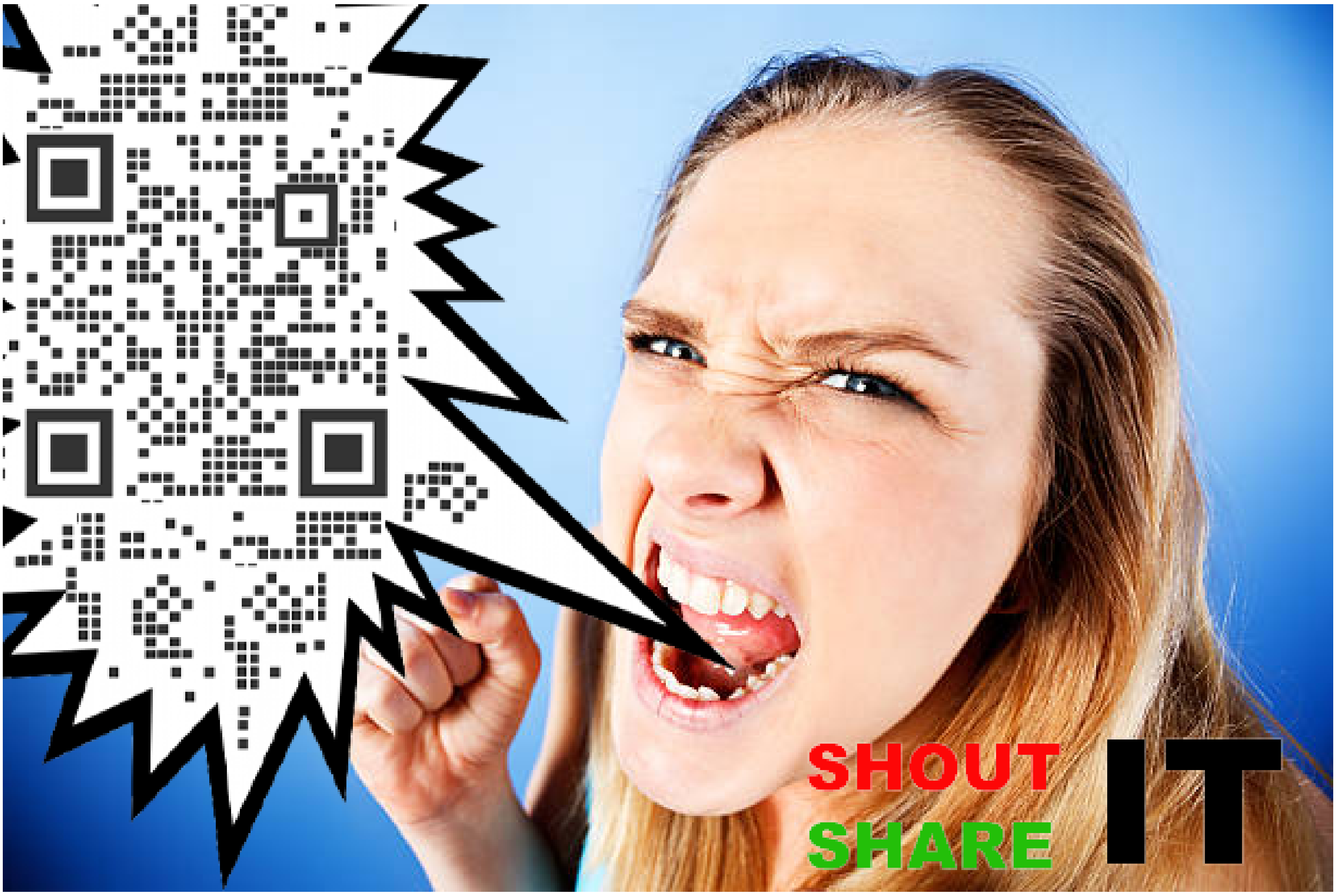
Food and Agriculture
Organization of the
United Nations

# Promoting innovation and tradition

## Solutions for climate change adaptation in mountains

Mountain Partnership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# Promoting innovation and tradition

## Solutions for climate change adaptation in mountains

Food and Agriculture Organization of the United Nations

Rome, 2024

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# Foreword

Although living at altitude has never been easy – and mountain communities have long demonstrated exceptional ingenuity in thriving in harsh environmental conditions – the escalating impacts of climate change pose unprecedented challenges to mountain people, threatening their traditional ways of life and survival strategies.

Even today, mountain people continue to apply their traditional knowledge combined with innovative techniques to adapt to the changing climate; over generations they have refined ways to farm in difficult conditions and produce a wide variety of crops that are adapted to a range of different elevations, slope conditions and microclimates.

We should not forget that mountain ecosystems provide vital services well beyond mountain areas, such as water, forests, biodiversity, carbon storage and cultural values that are crucial for the life of billions of people in the surrounding areas and the lowlands.

Nature-based solutions are pivotal for conserving environments and fostering climate adaptation in mountains. Yet impactful nature-based solutions require long-term investment, cross-sectoral planning, inclusive governance frameworks and broad multi-actor engagement, including gender mainstreaming.

This publication discusses how mountain adaptation solutions contribute to addressing the climate crisis. All the case studies included here were provided by Mountain Partnership Members. By presenting their concrete adaptation efforts in mountain regions worldwide we want to highlight the role of local actors, especially women farmers, Indigenous Peoples and youth as principal agents of change.

The year 2023 marked a turning point for the mountain agenda on climate change. Mountains were recognized in the first global stocktake document presented at the 28th Conference of the Parties (COP 28) to the UN Framework Convention on Climate Change (UNFCCC),[1] as well as in the first-ever expert dialogue on mountains and climate change, which took place at the 60th session of the Subsidiary Body for Scientific and Technological Advice (SBSTA 60) in Bonn, Germany.

The Five Years of Action for the Development of Mountain Regions 2023–2027,[2] proclaimed by the United Nations General Assembly and the Global Action Plan on Mountain Regions' Development[2] developed upon request by the Food and Agriculture Organization of the United Nations (FAO) Council 174[3] and endorsed by FAO Governing Bodies, provide a global framework for FAO

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[1] **United Nations Framework Convention on Climate Change (UNFCCC)**. 2023. Draft decision -/CMA.4: Further guidance on the Glasgow Climate Pact. Conference of the Parties serving as the meeting of the Parties to the Paris Agreement.https://unfccc.int/sites/default/files/resource/cma2023_L17_adv.pdf.

[2] **FAO**. 2024. Global Action Plan on Mountain Regions' Development. Rome. https://openknowledge.fao.org/items/1139e3c0-c8b6-4fe9-95f7-5f0a7d1cf17a

[3] **FAO**. 2023. Report of the FAO Council: 174th Session. Rome. https://openknowledge.fao.org/server/api/core/bitstreams/ea99cfa4-a841-44b3-928c-823eca7c3da7/content

Member Nations and other stakeholders to intensify their efforts and reaffirm the importance of climate action for sustainable mountain development.

The FAO Strategy on Climate Change 2022–2031[4] and Action Plan 2022–2025[5] reflect FAO's strengthened support to Member Nations in their ambitions to implement the Paris Agreement and other relevant frameworks, while addressing biodiversity loss, desertification, land and environmental degradation, the need for accessible, affordable renewable energy, and food and water security.

The publication is also a contribution to the celebration of International Mountain Day 2024, which takes the theme "Mountain solutions for a sustainable future – innovation, adaptation and youth". In 2025 the International Year of Glaciers' Preservation, will also be another important step in recognizing the urgency to preserve glaciers and they role in water provision and to encourage the exchange of knowledge and best practices regarding glacier preservation and adaptation strategies. We hope that this publication will contribute to supporting urgent climate action in mountains and that mountain issues, and particularly mountain agrifood systems, are integrated into national policies as key solutions for addressing food insecurity and poverty, climate change, biodiversity loss, land degradation in mountains.

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[4] **FAO**. 2022a. FAO Strategy on Climate Change 2022-2031. Rome. https://openknowledge.fao.org/server/api/core/bitstreams/f6270800-eec7-498f-9887-6d937c4f575a/content

[5] **FAO**. Food and Agriculture Organization (FAO). 2022b. FAO Action Plan 2022–2025 for the implementation of the FAO Strategy on Climate Change. Rome. https://openknowledge.fao.org/handle/20.500.14283/cc7014en

# Abbreviations

| | |
|---|---|
| a.s.l | above sea level |
| ARPA VdA | Agenzia Regionale per la Protezione dell'Ambiente della Valle d'Aosta |
| AUBNCC | American University of Beirut Nature Conservation Center |
| BIA | Business Incubator and Accelerator |
| CAMON | Central Asia Mountain Observatory Network |
| CAVU | Climate Advocates Voces Unidas |
| CBD | Convention on Biological Diversity |
| CIC | Climate Innovation Challenge |
| CLC | Community Learning Centre |
| COP | Conference of the Parties to the United Nations Framework Convention on Climate Change |
| CONICET | Consejo Nacional de Investigaciones Científicas y Técnicas |
| CRI | Climate Risk Insurance (programme) |
| DRM | disaster risk management |
| DRR | disaster risk reduction |
| EbA | ecosystem-based approach |
| EDYTEM | Environnements, Dynamiques et Territoires de Montagne |
| FAO | Food and Agriculture Organization of the United Nations |
| FFS | Farmer Field School |
| FGR | forest genetic resources |
| FONAG | Fondo para la Protección del Agua |
| GEF | Global Environment Facility |
| GHG | greenhouse gas |
| GRAPE | Green Resilient Agriculture Productive Ecosystems (project) |
| ha | hectare |
| HUC | Himalayan University Consortium |
| IANIGLA | Argentine Institute of Nivology and Glaciology |
| ICL | Imperial College London |
| ICCA | Indigenous and Community Conserved Areas |
| ICIMOD | International Centre for Integrated Mountain Development |
| ICRC | Colombian Red Cross |
| IFMGA | International Federation of Mountain Guides Association |
| INRAE | French National Institute for Agriculture, Food and Environment |
| IPCC | Intergovernmental Panel on Climate Change |
| IYGP 2025 | International Year of Glaciers Preservation |
| KMD | Kenya Meteorological Department |
| LT-LEDS | long-term low greenhouse gas emission development strategy |
| M&D | Migrations & Développement |
| MP | Mountain Partnership |
| MPS | Mountain Partnership Secretariat |
| MWCA | Mongolian Wool and Cashmere Association |
| NAP | national adaptation plan |
| NBSAP | national biodiversity strategy and action plan |
| NDC | nationally determined contribution |
| NGO | non-governmental organization |
| NSW | New South Wales (Australia) |

| | |
|---|---|
| NWP | Nairobi Work Programme |
| OeAW | Austrian Academy of Sciences |
| RKMVERI | Ramakrishna Mission Vivekananda Educational and Research Institute |
| RUAF | Resource Centres on Urban Agriculture & Food Security Foundation |
| SBSTA | Subsidiary Body for Scientific and Technological Advice |
| SCALA | Scaling up Climate Ambition in Land Use and Agriculture |
| SHG | self-help group |
| SLM | sustainable land management |
| SMG | sustainable mountain guiding |
| UCA | Université Clermont Auvergne |
| UNDP | United Nations Development Programme |
| UNFCCC | United Nations Framework Convention on Climate Change |
| UNIBE | University of Bern |
| UNIFI | University of Florence |
| UNIGE | University of Geneva |
| UNIGRAZ | University of Graz |
| UoR | University of Reading |
| UREP | Grassland Ecosystem Research Unit |
| UQ | University of Queensland |
| VICAM | Vicuñas, Camelids and Environment (project) |
| WBR | World Biosphere Reserve |
| WFP | World Food Programme |
| WOCAT | World Overview of Conservation Approaches and Technologies |
| WT | water table |
| ZNIEDR | Zone Naturelle d’Intérêt Ecologique et de Développement de la Résilience |

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# Executive summary

The rate of temperature rise, coupled with the many other facets of climate change predicted for the coming decades, will have massive implications for people, their homes, landscapes and livelihoods wherever they may live on this planet. Those who reside in mountain regions are no exception, although the impact of climate change on these areas, and the people who call mountains home, has often received scant acknowledgement.

The implications of climate change for the more than 1.1 billion people who live in mountains, and for many who do not, cannot be overstated. Put quite simply, the rate of global warming of 1.5 °C above pre-industrial levels – the ceiling set by the Paris Agreement in 2015 – will be too much for mountain ecosystems to withstand in their present form. Mountains, which account for around one-quarter of the Earth's surface, are among the most biodiverse areas on the planet, but they are also among the most vulnerable.

Given their often harsh and fragile environments, mountain regions stand to suffer irreparable damage from the climate shifts that are forecast, and indeed whose effects are already being felt in many upland areas. First and foremost are the declines in snow and ice, with all that this entails in terms of compromised water availability, food production and revenues that depend on snow-based tourism. Increased and more extreme hazards, such as floods, landslides and lake outbursts, threaten mountain communities' lives and livelihoods.

The 26 case studies presented in this publication, all drawn from the experiences of Mountain Partnership Members, explore actions being implemented in mountain regions around the world in a range of sectors and settings to adapt to climate challenges. They include sustainable crop, livestock and water management practices, use of protected areas, adaptation strategies for forests and cities, and the promotion of social business entrepreneurship and sustainable investments in mountain value chains. Also featured are examples of initiatives to build resilience to disaster and climate risk, integrate knowledge and education at local level, and develop data and monitoring to ensure effective adaptation in mountain environments.

The common thread that runs through almost every story is the determination of local mountain people – many of them women, youth and Indigenous Peoples – to take their future into their own hands and design and put into practice real adaptive mechanisms that will protect, or adapt, their way of life and their environment. Some of the solutions involve harnessing traditional knowledge, while others are based on more innovative techniques, and several combine a powerful blend of both.

A number of the methods described here are practical and replicable solutions, which could be rolled out in other mountain settings facing similar challenges. A case in point is an FAO-led scheme to construct artificial glaciers in the mountains of Kyrgyzstan, where erratic and reduced precipitation is threatening livestock and crop farmers, as well as communities at lower altitudes. To date, 20 such glaciers have been built, often through community collaboration, and there are plans to extend the relatively low-cost technique to other parts of this mountainous nation.

Other case studies showcase an impressive array of solutions, many of them participatory, including the rescue of native beehives in Peru, diversifying from snow-based tourism in the European Alps, organizing community-led prevention of wildfires in Lebanon, developing a climate-resilient city in Colombia, introducing satellite-based climate risk insurance for farmers in Nepal, and involving women and young people in restoring the degraded biodiversity of the Togo-Ghana Highlands in Africa.

However, this is not just a book for and about mountain people. The publication also examines the repercussions of climate change on critical services that people who live in lowland areas depend, though many of them may not know it. Chief among these are food security, water and biodiversity, but also important are carbon storage and traditional products that are appreciated by millions of people who may never have visited a mountain location.

The efforts described in this report are being made at a time when mountains are at last gaining recognition within the climate change agenda. In 2023, they were singled out for special attention in a range of key international debates and fora on this critical issue, and it is essential that this momentum be maintained.

This publication is intended as a source of inspiration for potential solutions to the climate change challenges facing many mountain communities, ecosystems and economies. As well as the experiences documented in the case studies themselves, it also provides a rich selection of useful resources, including databases, many of them open access, and other details of activities and projects that are supporting climate resilience in mountain regions at global, national and local levels.

Chui steppe, Russian Federation

© Vladimir Ivanov

# 1

# Mountains and climate change

Nuptse, Nepal

© Brittany Mumma

Over the centuries, mountain communities have developed solutions to adapt to their harsh environments and protect or restore biodiversity and ecosystems in their territories. However, a rate of global warming of 1.5 °C above pre-industrial levels – the ceiling set by the Paris Agreement in 2015 – will be too much for mountainous ecosystems to be preserved in the long term.

Covering around one-quarter of the Earth's surface, in 2017 mountains were home to about 1.1 billion people (Romeo *et al.*, 2020) and are reservoirs and hotspots of high biological and cultural diversity. They play a crucial role in maintaining global water supplies and contributing to food security: glaciers, snow, permafrost and river basins with headwaters in the mountains supply freshwater, including for irrigation, to mountain residents and to billions of people in the lowlands.

The projected effects of climate change will bring profound and irreversible losses in mountains, as highlighted in the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2018; IPCC, 2022a; IPCC, 2022b).

The negative consequences of climate change are widespread and will affect ecosystem integrity (including the risk of mountain species extinction), ways of life, cultural identities, livelihoods, infrastructure and the economy at large across all mountain ranges. These effects will be driven mainly by the melting of glaciers, the decline in snow and ice, shifts in the water cycle and changes in hazards, such as floods, landslides and lake outbursts, related to increased extreme precipitation.

The changes will pose challenges for water supply, energy production, agriculture, forestry and tourism activities in the various mountain regions. The effects, closely intertwined with biodiversity loss and land degradation, will compound the vulnerabilities of many mountain communities that are highly dependent on natural resources and on small-scale and family-based crop and livestock production for their livelihoods.

People in mountain regions are among the world's poorest and half of rural mountain dwellers living in developing countries face food insecurity (Romeo *et al*., 2020). Access to services and infrastructure is weaker in mountains than in other areas. The multiple impacts of climate hazards on the vulnerable livelihoods of mountain societies are increasing human mobility in its various forms, including disaster displacement, planned evacuation, pastoralism and labour migration (IOM and MP, 2024). Poverty, marginalization and inequitable gender dynamics are among the root causes of the vulnerability of mountain people to climate risks.

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### Further reading

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Woman ploughing field, Nepal

# 2

# Implementing solutions for climate resilience in mountains

> *"Resilient and healthy mountain ecosystems are key for climate change adaptation and mitigation and for agrifood systems transformation. We must innovate, invest sustainably and empower local communities as stewards of their mountain environments."*
>
> **FAO Director-General Qu Dongyu**

© Sitaram Magar

People collecting forage to feed animals on the road between Kathmandu and Sandhikharka, Nepal

© Chris Steele-Perkins/Magnum

Mountain communities are the custodians of valuable traditional knowledge and practices. Small-scale farmers and pastoralists are the primary producers and consumers of food. They manage a wide genetic variety of agricultural crops and farm animals in a multitude of agroecological zones that are the result of differences in altitude and the prevalence of varied landscapes. This high genetic diversity found and maintained in mountain agrifood systems is a prerequisite for adaptation to new conditions and is likely to be key to the future of world food security in the face of climate change by providing a gene pool of resilient crops (Barchiesi *et al*., 2022).

The importance of highly heterogeneous mountain agrifood systems in addressing the interlinked challenges of climate change, biodiversity loss and land and soil degradation needs to be recognized and supported. Local and community-led action – with farmers as key agents of change and practices adapted to local contexts – which consider the entire systems' health and functionality need to be part of the solutions for strengthening the resilience of mountainous ecosystems.

Despite considerable efforts, the IPCC notes that the majority of adaptations observed in mountainous regions are still predominantly incremental in nature (Adler *et al*., 2022). This implies that they maintain the fundamental characteristics and integrity of existing systems at a given scale (IPCC, 2014). Transformative adaptation offers a range of benefits for land management, biodiversity, food security, climate change mitigation and risk management.[1]

Transformative adaptation can be defined as a system-wide change that alters the fundamental attributes of a defined system in anticipation of climate change and its impacts, encompassing technological, social and economic aspects (Adler *et al.,* 2022), while generating broader changes on aspects of development through adaptation activities (Few *et al*., 2017). This approach can facilitate rapid change at scale by addressing the underlying drivers of vulnerability to climate risk (Fedele *et al*., 2019) and the economic, social and environmental sustainability of that change (FAO and UNDP, 2022).

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[1] The FAO Strategy on Climate Change 2022–2031 and Action Plan 2022–2025 support transformative adaptation through three pillars: 1) advocacy at global and regional levels; 2) policy support at country level; and 3) the scaling-up of climate action on the ground with local actors and vulnerable populations.

Key policy instruments for enhancing climate and biodiversity action in mountain regions are supported by international agreements, such as nationally determined contributions (NDCs), national adaptation plans (NAPs) and long-term low greenhouse gas emission development strategies (LT-LEDS) under the UNFCCC, as well as national biodiversity strategies and action plans (NBSAPs) under the Convention on Biological Diversity (CBD) and the Sendai Framework for Disaster Risk Reduction 2015–2030.

The Paris Agreement, adopted by 196 Parties at the United Nations Climate Change Conference (COP 21) in Paris on 12 December 2015, strengthens the global response to combat climate change and adapt to its impacts by providing a critical and collective framework to enhance adaptive capacity, strengthen resilience and reduce vulnerability to climate change (Article 7) by "holding the global average temperature increase to well below 2° C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels" (Article 2). The agreement commits all Parties to prepare, communicate and maintain NDCs on a five-year cycle and to implement national actions to achieve them (Article 4). It also recognizes the importance of preventing, minimizing and addressing loss and damage related to the adverse effects of climate change (Article 8) (UNFCCC, 2015).

The Global Action Plan on Mountain Regions' Development, in support of implementation of the United Nations Five Years of Action for the Development of Mountain Regions 2023–2027 (FAO, 2022a) showcases 27 FAO projects and initiatives (FAO, 2022c),[2] while calling for more and wider efforts by all stakeholders at the global, national and local level to contribute to the five years of action.

Scaling up nature-based solutions to reduce climate risks and promote adaptation and mitigation in mountain areas is one of the key pathways of the Global Action Plan.[3]

Actions include: adopting integrated approaches for the promotion of sustainable agrifood systems, biodiversity conservation, sustainable silvopastoral methods, sustainable forestry, soil and water management; conserving and restoring mountain ecosystems; promoting sustainable tourism; and giving priority to mountain-related issues in the development and revisions of NDCs, NAPs, LT-LEDS and NBSAPs.

Actions included under the other pathways can contribute to building climate resilience by improving mountain communities' access to services and sustainable infrastructure (including disaster risk preparedness), empowering mountain communities and reducing inequalities, with a priority focus on women, youth, Indigenous Peoples and local communities, and enhancing international cooperation, security and multilevel governance in mountain regions.

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[2] In addition, 41 more initiatives are listed under the Global framework for the Five Years of Action for the Development of Mountain Regions 2023–2027.

[3] The four interrelated pathways are:

- scale-up nature-based solutions to reduce climate risks and promote adaptation and mitigation in mountains; improve access to services and sustainable infrastructure for mountain communities; enhance international cooperation, security and multilevel governance in mountain regions; and empower mountain communities and reduce inequalities, with a priority focus on women, youth, Indigenous Peoples and community-based populations.

FAO's climate change strategy emphasizes the use of ecosystem-based approaches (EbA) for adaptation solutions (FAO, 2022b). EbA refers to the use of biodiversity and ecosystem services as part of an overall strategy to help people adapt to the adverse effects of climate change. In mountain regions, where ecosystems are diverse and highly sensitive to climate impacts, EbA focuses on conserving, restoring and managing these ecosystems to enhance communities' resilience to changing environmental conditions.

Specific opportunities for EbA in mountains include:

- Biodiversity preservation and carbon sequestration: Mountain ecosystems support a large portion of global biodiversity, and act as significant carbon sinks.
- Water security: Mountains are often referred to as 'water towers' because they supply freshwater to downstream areas.
- Livelihood enhancement: EbA approaches, such as integrating agroforestry or ecotourism, can offer alternative income sources for mountain communities, improving their resilience to climate risks while conserving ecosystems.

Successful EbA in mountain regions will depend on inclusive decision-making, capacity development and securing sustainable financial support to address both environmental and socioeconomic vulnerabilities (Adler *et al.*, 2022).

Mountains are critical to climate change adaptation, disaster risk reduction (DRR) and disaster risk management (DRM) due to their ecosystem services and their role in regulating water cycles. Climate change is affecting the timing, frequency and location of geohazard events with potential cascading effects. Slope stability and flood risk can be impacted by glacial recession and permafrost thaw in high-mountain and subartic regions. Continuous glacier retreat also leads to extreme events and new and evolving disaster risks for downstream populations and vulnerable transport and energy infrastructure, such as glacier lake outburst floods, landslides or enhanced erosion and sediment. (Adler *et al.*, 2022).

The UNCCD and partners emphasize the role of sustainable land management (SLM) practices in combating erosion, which is a significant issue in mountainous regions. Erosion in these areas can lead to loss of soil fertility, reduced agricultural productivity, and increased vulnerability to disasters such as landslides. The solutions highlighted (UNCCD, 2024) include: 1) Reforestation and afforestation – to help stabilize soils, reduce runoff and enhance biodiversity. 2) Agroforestry – integrating trees with crops improves soil structure and moisture retention. 3) Terracing – which can be useful in mountainous regions for controlling water flow, preventing soil erosion and maintaining agricultural productivity. 4) Sustainable grazing management – since preventing overgrazing by livestock is critical for maintaining ground cover and preventing soil degradation.

Achieving land degradation neutrality requires maintaining the quality of existing healthy land, reducing further degradation through the adoption of SLM practices, and restoring already degraded lands to a more productive state. However, the implementation of these solutions must be context-specific, respecting local biodiversity and ecosystems while also integrating the needs of the local population (UNCCD, 2024.)

### Box 1. Selected web resources on adaptation practices

A vast number of resources are available on activities and projects to support climate resilience in mountain regions at global, national and local levels. Several organizations maintain databases with free access to practices and information that support the exchange of experiences.

**The UNFCCC Adaptation Knowledge Portal.** The Adaptation Knowledge Portal is an online resource of the UNFCCC Knowledge-to-Action Hub for Climate Adaptation and Resilience, also called the Nairobi Work Programme (NWP). Mountains are one of the priority thematic areas under the NWP on impacts, vulnerability and adaptation to climate change. The Adaptation Knowledge Portal provides free and open access to adaptation knowledge resources. The portal provides information on the NWP's network of more than 400 leading and diverse partner organizations, as well as engagement opportunities. It builds on the contributions of policymakers, practitioners and researchers to offer informed and credible adaptation knowledge and learning.

**The Global Database on Sustainable Land Management of the World Overview of Conservation Approaches and Technologies (WOCAT)** provides free access to the documentation of field-tested SLM practices from different places in the world and offers practitioners the opportunity to share their own SLM practices. Due to its long-term presence and wealth of knowledge, WOCAT's database has been officially recognized by the UNCCD as the primary recommended global database for SLM best practices.

**Adaptation at Altitude Solutions Portal:** The Adaptation at Altitude programme manages a Solutions Portal to support mountain communities in adapting to climate change. The Adaptation at Altitude Solutions Portal gives visibility to solution providers and makes tested, replicable solutions from mountain regions around the world easier to find and explore, providing inspiration and support to stakeholders and decision-makers. Currently, the portal features more than 100 solutions, each offering detailed information on where they have been implemented and insights into successful strategies in mountain regions.

ADAPTATION
AT ALTITUDE
Latest solutions

STRENGTHENING CRITICAL INFRASTRUCTURE AGAINST NATURAL HAZARDS PROJECT: TAJIKISTAN

WOMEN-CENTRIC APPROACH TO ENHANCE RESILIENCE IN KAVRE DISTRICT, NEPAL

RESTORING ANCIENT WATER MANAGEMENT SYSTEMS IN THE HIGH ANDES AS AN ADAPTATION TO CLIMATE CHANGE - MIRAFLORES, PERU

**The DRR Knowledge Base portal** of the United Nations Office for Disaster Risk Reduction includes resources on community-based DRR solutions, environment and ecosystems, cultural heritage and other mountain-related themes.

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Mountain meadows of Gergeti, Georgia

# 3

# Case studies – action to adapt to climate change in mountain regions

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Community climate action laboratories in the moorland areas, Colombia

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Successful adaptation practices in mountain agrifood systems need to address the interlinkages between climate, food, nutrition, water, land, biodiversity and energy, and ensure a 'just transition' and social inclusion of climate action. Gender-sensitive action, coupled with the integration of local perspectives and the bridging of local knowledge and science, are essential in order to prevent and minimize maladaptation and reduce inequalities and inequities based on gender.

Underlying factors for successful adaptation include good governance and tackling drivers of vulnerability, ensuring land tenure security and rights for local people and addressing conflicts over mountain resources (caused by mining, industrial activities, land grabbing and/or conflicting land uses).

The following is a selection of case studies, all drawn from the experiences of Mountain Partnership Members, which explore actions to address climate change being implemented in mountain regions around the world.

The case studies are organized under seven themes: Sustainable crop and livestock practices; Water management for adaptation; Protected areas, forests, green cities; Social business entrepreneurship and sustainable investments in mountain value chains; Building resilience to manage disaster and climate risk for mountain people; Integrating knowledge and education at local level for just adaptation and development; and Data and monitoring.

Annex 1 presents an overview of the adaptation practices implemented by each case study.

# 3.1 Sustainable crop and livestock practices

Approaches to building resilience include crop cultivation and livestock production methods that promote locally adapted crops and breeds and drought-tolerant varieties, and prioritize products with high nutritional content and resilience to climate stress, as well as specialty products.

Technologies include agroecology for the enhancement of moisture retention, improvement of soil fertility, terracing against water and wind erosion, and the protection of soil and biodiversity.

Integrating trees on farms increases the resilience of livelihoods and landscapes to shocks and stresses. Agroforestry promotes diversity in production systems and helps to reduce crop losses from climate-induced pests and diseases, improving soil health and contrasting erosion, protecting farms from extreme weather events (Libert-Amico *et al*., 2022).

Read more on opportunities and best practices for inclusive and resilient mountain food systems.

Read more on understanding mountain soils and sustainable soil management in mountain regions.

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### 3.1.1 Building local capacity and leadership in high mountain communities of Colombia

The FAO–United Nations Development Programme (UNDP) initiative on **Scaling up Climate Ambition in Land Use and Agriculture through nationally determined contributions (NDCs) and National Adaptation Plans (NAPs) (SCALA)** is supporting 12 partner countries in Africa, Asia and Latin America to bring about transformative climate action. Using countries' NDCs and NAPs as entry points, SCALA identifies pathways for moving from planning to implementation of climate change adaptation and mitigation solutions in alignment with other goals, supporting collaboration with the private sector, as well as inclusive and gender-sensitive approaches.

Colombia hosts 10 percent of the world's biodiversity, encompassing tropical high mountain ecosystems and a significant portion of global moorland areas. These ecosystems are a vital source of water, an effective resource for carbon storage and sequestration, and a biodiversity hotspot (Burbano-Girón *et al.*, 2021). However, the threat of climate change is accelerating the rate of land degradation and biodiversity loss in these unique and fragile ecosystems, linked to rising temperatures, droughts, floods and changes in mean annual precipitation (Bejarano *et al.*, 2022). To address this, SCALA is working with local high mountain communities to build capacity, tools and community knowledge to implement concrete adaptation actions.

SCALA has pioneered several innovative solutions in two high mountain areas of significant ecological value: the moorland areas of Chingaza and Sumapaz. These include the creation of two territorial observatories – collaborative spaces between farming communities and local universities – to facilitate the participatory collection, analysis and dissemination of information about key agrifood systems and the impacts of climate change, as well as the development of two participatory assessments, strengthening local traditional knowledge and the understanding of climate risks and vulnerabilities, while facilitating local planning, action and public policy.

Further, SCALA has established four community climate action laboratories in collaboration with local communities and farmers' associations, and 15 additional local collaborations under the Global Environment Facility (GEF) Small Grants Programme. These laboratories serve as community-based experimental platforms focused on training, learning and dialogue for the collective development and design of climate and agrobiodiversity adaptation actions to address identified risks and vulnerabilities (Peña-Torres and Reina-Rozo, 2022). SCALA facilitates the implementation of sustainable agroecological adaptation practices, including the establishment of community nurseries, the rescue and utilization of native tubers and beehives, and the optimization of irrigation systems to enhance resilience to droughts and changing precipitation.

SCALA is also supporting the recovery and systematization of 15 adaptation practices and techniques based on Indigenous Peoples and local traditional knowledge and agrobiodiversity, as well as the first pilot of the **certification of agriculture adapted to climate change** in various value chains and mountain regions across the country. This has enabled the identification of locally relevant adaptation pathways, guiding the actions of small- and medium-scale producers through transparent and evidence-based local monitoring systems.

Community nursery under the climate action laboratory of the Sumapaz moorland area, Colombia

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The experience of the SCALA initiative in Colombia illustrates the importance of meaningful engagement of and support for local communities and Indigenous Peoples as key agents of change. This includes the reinforcement of local knowledge, capacity and resources to transition from planning to the informed implementation of adaptation measures, in line with local contexts and realities. As a result, the programme has facilitated the recognition and promotion of diverse knowledge systems and ensured sufficient time and resources for their meaningful participation and contribution in the implementation of NDCs and NAPs. These tools and methodologies are being piloted and scaled up in different territories, contributing to the development of ecosystem-based and community-led adaptation strategies that offer practical and replicable solutions for sustainable food production, food security and agrobiodiversity in Colombia's high mountain areas.

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### 3.1.2 Alpine farmers face up to climate change

In recent decades, Alpine forage-livestock systems have experienced dramatic variations in mountain grasslands and their management (Herzog and Seidl, 2018; Dibari *et al*., 2020).

In the framework of the LIFE PASTORALP project Pastures vulnerability and adaptation strategy to climate change impacts in the Alps, an integrated method to assess and test effective adaptation measures was proposed in two national parks of the western Alps: Écrins (France) and Gran Paradiso (Italy). The approach combines an analysis of current regional, national and European policies, a modelling approach based on remotely-sensed imagery, and participatory processes with farmers, technicians, shepherds, researchers and officials of local institutions.

**Table 1. Adaptation policies for the sustainability of summer mountain pastures in the northwestern Alps**

| Scope | Issue | Adaptation policies |
|---|---|---|
| Technical adaptations to climatic hazards | Adaptation of the pastoral system | Discuss Common Agriculture Policies (CAP) measures to make the use of mountain pastures more flexible |
| | Optimization of pastoral management | Fund structural/infrastructural upgrades (watering, tracks, edifices) |
| | | Support the implementation and use of pastoral management plans |
| Water management | Reduction of conflicts for water | Promote participatory watershed management |
| | Increased production capacity | Improve the water network and management at the pasture scale |
| Multifunctionality | Development of local economy | Raise farmers' incomes through other agricultural or tourist revenues |
| | Mutual understanding between the different actors | Raise awareness of environmental, economic and social peculiarities of mountain areas and improve cohabitation between residents, farmers and tourists |
| Cooperation and training | Skills of pastoralists | Promote the organization of training courses |
| | Capacity building | Implement cooperation measures between farmers and other actors |
| | Collaboration between farmers, citizens and institutions | Integrate agricultural agents in local administrations and protected areas |
| Biodiversity and agroecology | Preserving biodiversity | Develop ecopastoral management for target species, habitats and High Nature Value areas |
| | | Promote payments for environmental services to pastoralists |
| | | Preserve biodiversity hotspots and agroecological networks |

*Source:* Authors' own elaboration

Herder in the Gran Paradiso National Park, Italy

© Marzia Verona

## Table 2. Feasible measures for climate change adaptation in summer mountain pastures in the study areas

| Climatic hazards | Consequences for the natural environment and pastoral system | Adaptation measures |
|---|---|---|
| Very dry winter or late or cold spring | Poor grass production and/or decline of pasture quality | Increase grazing of coarse vegetation or shrubs |
| | | Reduce herd size or delay the first grazing date |
| | | Search for additional pastures (brush clearing, improve barns and trails) |
| | | Permanently modify the first grazing dates |
| | | Modify weaning dates |
| | | Change livestock category, breed or species |
| Early spring | Very advanced plant phenology | Tighten herding in productive grasslands |
| | | Anticipate the grazing period |
| Shallow snowpack | Poor biomass in pastures at higher altitude (scarce water stock) | Shorten the grazing period in the highest grasslands |
| | | Graze on low-lying wooded areas |
| | | Withdraw part of livestock from summer mountain pastures |
| Spring drought | Quick grass drying | Increase grazing of coarse vegetation or shrubs |
| Heatwave and wind in June | Contemporaneity of grass maturity | Tighten herding in productive grasslands |

| | | |
|---|---|---|
| Very hot and dry summer, heatwave and drought | Source dry out (watering and irrigation problems) | Change grazing timetables (earlier, later, night grazing) |
| | | Adapt pasture routes for watering animals |
| | | Rationally manage waterpoints in pastures |
| | | Search for long lasting supply solutions (e.g. catchments, reservoirs) |
| | | Restore traditional irrigation systems and improve irrigation efficiency |
| | Poor grass production | Search for additional grazing areas, such as wooded or shrubby ones |
| | | Stock reserves in winter farm by haymaking or hay purchasing |
| | | Supply fodder in summer mountain pastures |
| | | Restore or build structures in pastures |
| | Modification of pasture density and flora | Improve grazing efficiency (rotational grazing) and pasture management (e.g. manuring, weeding) |
| | Poor forage resource at the end of summer | Preserve late-growing grasslands for the end of the grazing season |
| | | Increase grazing of coarse vegetation at the end of the season |
| | | Exceptional early ending of the summer grazing season |
| | Adverse effects of heat stress on animals | Include and conserve shaded areas in low-lying pastures |
| Rainy summer | Onset of hoof diseases | Prepare animals for the grazing season (hoof-cutting, footbathing) |

*Source:* Authors' own elaboration based on the PASTORALP web platform (http://www.pastoralp.eu/tools)

The integrated strategy plan developed by PASTORALP to support pastoral communities' adaptation to climate change could serve as a starting point for wider application outside the European Union context, even though additional case studies and regional adaptations may be necessary as climate conditions continue to evolve.

Continuous updates and monitoring through the PASTORALP repository will be crucial, with an emphasis on the need for continuous local fine-tuning to assess feasibility and effectiveness over time.

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### 3.1.3 Valuing camelids in the Andes

South American camelids, which include two wild species: *guanacos* (*Lama guanicoe*) and *vicuñas* (*Vicugna vicugna*) and two domestic species: *llama* (*Lama glama*) and *alpaca* (*Vicugna pacos*), are useful species for reducing greenhouse gas emissions and supporting the adaptation of pastoral livelihoods to the impacts of climate change.

The Vicuñas, Camelids and Environment (VICAM) project in the *Puna*, also known as *Altiplano* of Jujuy, northwest Argentina, is based on the "nature contributions to people" (of the wild vicuña (which has been brought back from the brink of extinction) and the domestic *llama* (the ancient livestock of the Andes) in a co-constructed socioecological landscape (Arzamendia *et al*., 2021).

Pastoralism by Indigenous Peoples and local communities is the main traditional livelihood in this area's dryland mountains and is vulnerable to current and projected climate warming and droughts. A severe drought in 2017 prevented the *llama* herders from staging their traditional trek with *llama* caravans, disrupting an ancestral practice, as they estimated that they would not have enough grass or water for the journey (Vilá, 2018). Compared with European-origin livestock species (such as sheep, goats and cows), endemic *llamas* (and wild *vicuñas*) have displayed a number of adaptation strategies for coping with drought. These include efficient foraging of plant species with high fibre content (yellow grasses), lower intake compared with animals of the same biomass, and consequently, lower methane emissions (Vilá, 2012).

Wild *vicuñas* have co-evolved with the *Puna* steppe and can graze peacefully among the *llamas*, in an integral system that includes wild fauna and livestock (Arzamendia and Vilá, 2014). Both camelids are considered to be low-impact grazers, but both are also experiencing risks. *Vicuña* poaching is increasing due to the high economic value of the fibre, and *llama* herders are increasingly abandoning their livelihoods due to difficulties caused by countercultural policies, modifications in consumption patterns, low prices of mountain camelid products (fibre, garments and meat), and the establishment of mega-mining projects in the area.

Against this scenario, the VICAM project seeks to create a synergy that includes actions to protect camelid biodiversity and generate opportunities for communities, while contributing to climate change mitigation.

Together with local communities, the VICAM group was the first research team to develop the *chaku* – the traditional capture, shearing and release (back to

Herding vicuñas to the corral, Argentina

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nature) of wild *vicuñas* in Argentina – and to publish a manual of the techniques used, including animal welfare protocols (Baldo *et al*., 2013).

For domestic *llamas*, the annual *Ashka Llama* is a competition for different breeds and categories of *llama* to promote breeding; the VICAM team is part of the panel of judges and takes part in awarding the rosettes to the prize-winners. It also co-organizes a spinning context, as a way of disseminating knowledge about the care of *llama* herds.

Over the years, VICAM has proposed different environmental education strategies, targeting local schools and university students (Vilá *et al*., 2020). Schoolchildren become involved through writing poems, drawing and playing.

In terms of economic development, it has been shown that trading camelid fibre (from *llamas* and *vicuñas*) as a commodity for international textile companies does not generate the desired income for local communities. To address this issue, the VICAM team is working on enabling communities to develop their capacities to add value locally to *vicuña* and *llama* fibre, for use in the production of high-quality products. Scaling up these processes would require adequate policy support, to move from a pilot/research activity to a regional-level initiative.

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## 3.1.4 Stingless beekeeping and conservation in Lambayeque, Peru

Rural communities in the Lambayeque region of northern Peru are highly vulnerable to climate-related risks, such as unpredictable rainfall and rising temperatures, which have led to the degradation of natural habitats and a decline in biodiversity.

Stingless bees, which are essential pollinators within local ecosystems, are under increasing threat due to deforestation and agricultural expansion. This decline poses serious risks to food security and environmental sustainability, given the bees' critical role in pollinating native plants and crops. In addition, rural communities dependent on subsistence agriculture face economic challenges due to the reduced productivity caused by degraded land and shifting climate patterns.

Sumak Kawsay is an environmental enterprise based in the mountain village of El Higuerón, which promotes the conservation of native bees and other pollinators. The enterprise's name means 'good life, in harmony with nature' in the *Quechua* language of Peru. The initiative aims to conserve stingless bees by integrating meliponiculture – stingless beekeeping – with local conservation efforts.

Its activities are contributing to a range of outcomes, with benefits for local mountain communities and their environment. These include:

**Biodiversity conservation**: by promoting the restoration of native forests and establishing stingless bee colonies, the project is mitigating the effects of climate change by creating sustainable ecosystems. Stingless bees are crucial to maintaining the biodiversity of the region’s flora, enhancing pollination, and fostering ecosystem resilience. To date, Sumak Kawsay has planted more than 2 000 trees and is preserving three species of native stingless bees.

**Support to local livelihoods**: the production and sale of honey provide communities with a source of income, in addition to subsistence farming. The honey, known for its medicinal properties, has a high market value. The diversification of income sources, especially when linked to community-based agritourism ventures run by women such as The Bee Honey Route, has the potential to enhance the resilience of local livelihoods.

Women and vulnerable groups have gained increased opportunities for involvement in sustainable agriculture and tourism, which is improving their financial independence and quality of life.

**Ecosystem restoration**: the project emphasizes the importance of planting a variety of species. Together with local farmers, the project recovers seeds that have become extinct in the community and collects others from native trees, while learning about their multiple ecological functions, such as controlling soil erosion and attracting pollinators. The initiative has helped to restore degraded ecosystems , strengthening the resilience of mountain environments to climate-related stress.

Local populations are closely involved in every phase of the initiative. From youth participation in stingless beekeeping workshops to women’s leadership of agritourism activities, community engagement is key to the success of the project. The initiative enhances climate resilience by equipping communities with the knowledge and tools to manage their natural resources sustainably, ensuring that they can adapt to changing environmental conditions, while improving their livelihoods.

Stingless beekeeper Ysa Calderón, Peru

© Ysabel Agustina calderon carlos

To expand the initiative across other territories, several key conditions must be met:

*Financial investment* – Additional funding is required to conduct further honey analysis and research in other areas, which is vital for ensuring the quality of honey and identifying locations for ecosystem restoration. Investment in new bee colonies and infrastructure is also needed to expand production and conservation efforts.

*Capacity development* – Scaling-up requires training more community members in sustainable beekeeping and agritourism practices, particularly focusing on youth and women. Enhancing local capacities will enable communities to adopt meliponiculture more widely and manage their natural resources more effectively.

*Policy and market support* – National policies must support sustainable agricultural practices, including incentives for agroforestry and beekeeping. Improving market access for stingless bee honey and related products will boost economic returns for rural communities, fostering greater participation in conservation efforts.

## 3.2 Water management for adaptation

Water management and regulation are central to climate change adaptation. A large share of adaptation options is directly related to water and to water-related impacts of climate change – changing rainfall patterns, global warming and the increase in the occurrence of extreme events, including droughts and floods.

Water management for adaptation includes technologies, infrastructure and practices that sustain good soil moisture conditions for plant growth. They range from enhancing the capture and retention of rainfall, so as to ensure sufficient availability of water over time, to providing adequate drainage, so as to avoid and mitigate flooding (FAO, 2016). Pastoral adaptation options include seasonal migration of livestock herds to more fertile pastures and livestock insurance schemes (Fassio *et al*., 2014; Gentle and Thwaites, 2016; Tiwari *et al*., 2020).

Glacier monitoring provides important data for climate adaptation and mitigation strategies, but responses to glacier mass loss will need to be context-specific. In the short term, increases in runoff and water supply, linked to glacier melting, will have to be managed, while longer-term strategies will be needed to prepare for when glaciers can no longer play their role as stable and reliable sources of water, as their mass becomes depleted. These efforts will also help to avoid and mitigate conflicts related to water availability and use, including in cross-border settings.

Alongside efficient water use, the restoration and protection of particularly vulnerable areas, such as wetlands, is likely to be a way to implement water conservation measures (Adler *et al*., 2022).

Experimental setup. Blocked drainage ditches, Ecuador

© FONAG team

Under the Ramsar Convention on Wetlands, the definition of ‘a wetland’ also covers streams, lakes and rivers, which are closely connected to snow cover and glaciers. With the growing variability of rain and snowfall, the climate impact of aquatic ecosystems has become even more accentuated. The melting of glaciers coupled with increased rainfall has caused the size of wetlands to grow in some areas over the past few decades. However, this trend is predicted to be reversed due to a decrease in rainfall and glacier runoff. (Dangles *et al.*, 2017, Adler *et al.*, 2022).

Peatland restoration as part of broader landscape-level management has gained significant popularity and results. Rewetting of *páramos* and *bofedales* as adaptation, water and biodiversity efforts, including in Colombia, Ecuador and Peru, has resulted in reduced greenhouse gas emissions.[4] Some cases have also yielded improved drinking water availability to communities downstream (FAO, 2022). As with other ecosystems, protection from intense grazing and conservation can help them to adapt better to the changes that are taking place.

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[4] *Páramos* and *bofedales* are types of mountain wetlands in Latin America.

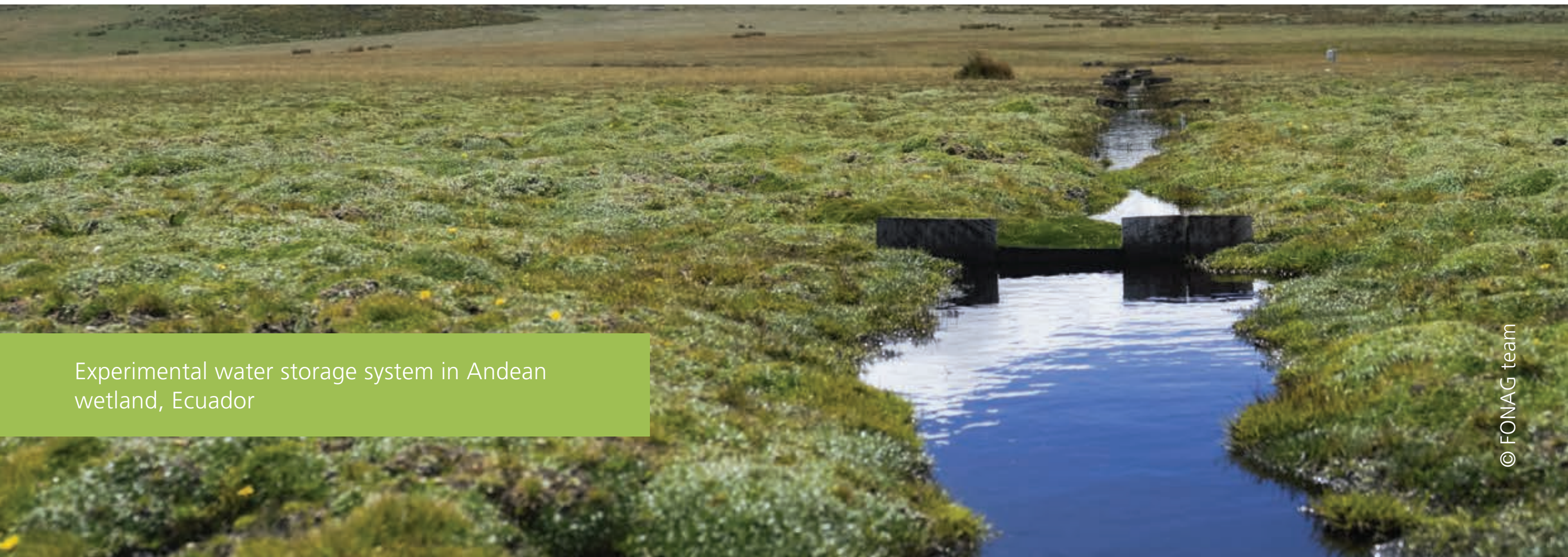
### 3.2.1 Rewetting Andean wetlands to enhance water availability

Hydrological regulation to yield stable flows in tropical Andean rivers is provided by water storage volumes, such as glaciers, but more importantly, storage in the soils and wetlands, very often peatlands. Whereas many studies have focused on glacier retreat under global warming and its hydrological impact (Thompson, 2000; Thompson *et al.*, 2003; Vuille *et al.,* 2008; Wang *et al.*, 2014; Chevallier et al., 2011), little has been said about the possible loss of water regulation capacity in the *páramo* ecosystem under warmer conditions (Buytaert *et al.*, 2010; Junk, 2013). The *páramo* is a mountain ecosystem of the Andean tropics situated above the tree line and the snow line, dominated by grasslands on soils with high organic carbon content.

Moreover, warming is expected to be enhanced at low latitudes and high altitudes, (Almazroui *et al.*, 2021; Buytaert *et al.*, 2010; Urrutia and Vuille, 2009), where the *páramo* ecosystem is located, between the tree line and the snow line. The water regulation capacity of the *páramo* ecosystem is very much related to the high organic matter content of its soils, and therefore vulnerable under warmer scenarios that could accelerate organic matter decomposition (Cresso *et al.*, 2020). Therefore, enhancing carbon storage in *páramos* should be seen as both adaptation to, as well as mitigation of climate change.

*Páramos* are water providers for many Andean cities. The city of Quito started to withdraw water from the Andean Eastern Cordillera at the end of the twentieth century. Nowadays, many of these areas are protected. For instance, the Antisana Water Conservation Area (AWCA), which is located at approximately 4 000 m above sea level (a.s.l) and provides around 1 600 litres per second of water to the rapidly growing south of Quito where low-income families live, is today managed by Quito's Water Fund FONAG, following delegation by the Municipal Water Utility EPMAPS - Agua de Quito.

Wetlands are important water sources in AWCA, but draining them was common practice under the previous land use of livestock grazing. This practice reduced water table (WT) levels and exposed peat to aerobic conditions, making it prone to decomposition. In 2018, FONAG restored Pugllohuma, an AWCA wetland, which has an area of 15 hectares (ha) and had 3 680 metres of human-made drainage ditches. The restoration strategy consisted of blocking the ditches using wooden boards fixed into the peat to reduce water energy during high-flow events, creating small dams and generating favourable peat accumulation conditions. Only monitoring action was undertaken, making it a low-cost intervention, easily applicable to larger scales.



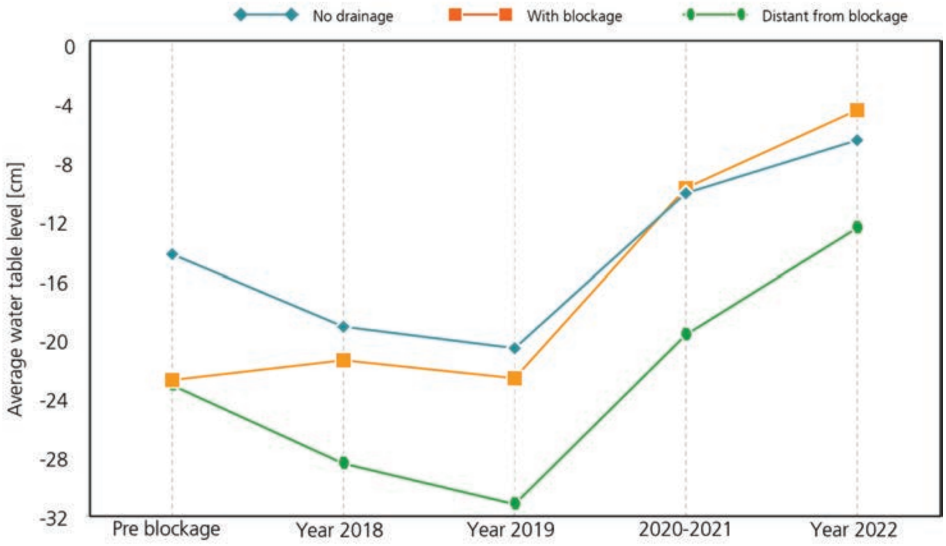
Experimental water storage system in Andean wetland, Ecuador

© FONAG team

The monitoring design consists of 18 wells where WT levels have been monitored since 2017. The first monitoring year served as a baseline before blocking the ditches. The WT increased on average 8.5 cm (10 percent of the mean annual precipitation, see Figure 1). Also, the WT recession constant (the hydrological parameter that shows the time it takes for a reservoir to become half-empty) went from 17 days in 2017 (pre-blocking) to 30 days in 2023, meaning that the residence time of water in the wetland increased, improving water regulation. Temporal changes were also determined in hydrophysical properties. The organic matter content (the proxy for carbon storage) increased from 59 percent in 2019 to 73 percent in 2022. Furthermore, a reduction in bulk density was observed (and therefore an increase in water storage capacity) (Buytaert *et al.*, 2002), with values of 0.25, 0.19 and 0.12 grams per cubic centimetres/cc for the years 2017, 2019 and 2022 respectively (see Figure 2).

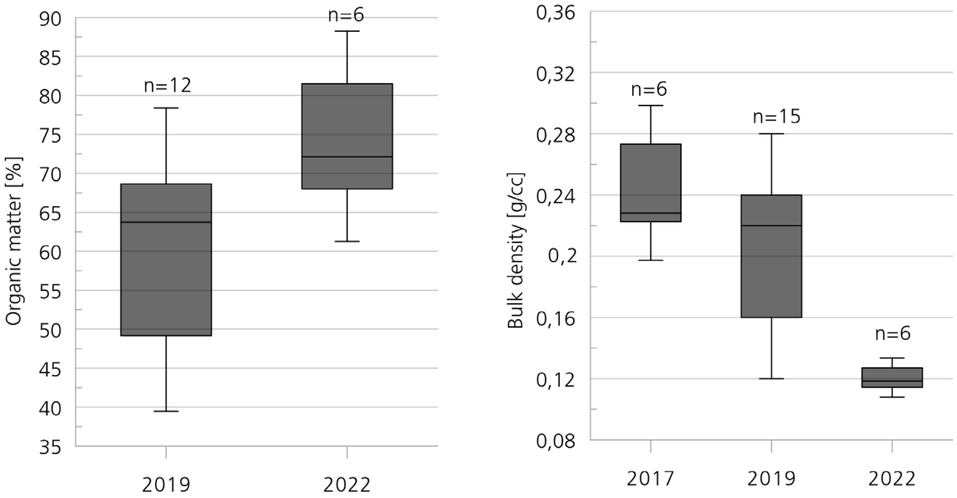
Even though Pugllohuma is a small-scale experiment and started as a water-related strategy, it shows how restored wetlands may contribute to the mitigation of climate change by accumulating carbon, while at the same time contributing to adaptation to water regulation capacity loss in other mechanisms. Given glacial retreat, wetlands become more important in terms of water and carbon dynamics in tropical highland ecosystems. In this case study, mitigation is achieved through rising WT levels and by creating positive feedback to accumulate organic matter (carbon). Finally, adaptation can be seen as improving water regulation and yield before the upcoming warmer conditions in the Andes.

**Figure 1. Temporal evolution of mean groundwater level before and after the blockage. Period 2017–2022. Wells with blocked drainage started to increase their mean water table after the restoration.**



*Source:* Authors' own elaboration

**Figure 2. Organic matter and bulk density at 0-20 cm soil depth in the Pugllohuma wetland. Organic matter increases and bulk density reduces after the restoration. n = number of samples per year.**



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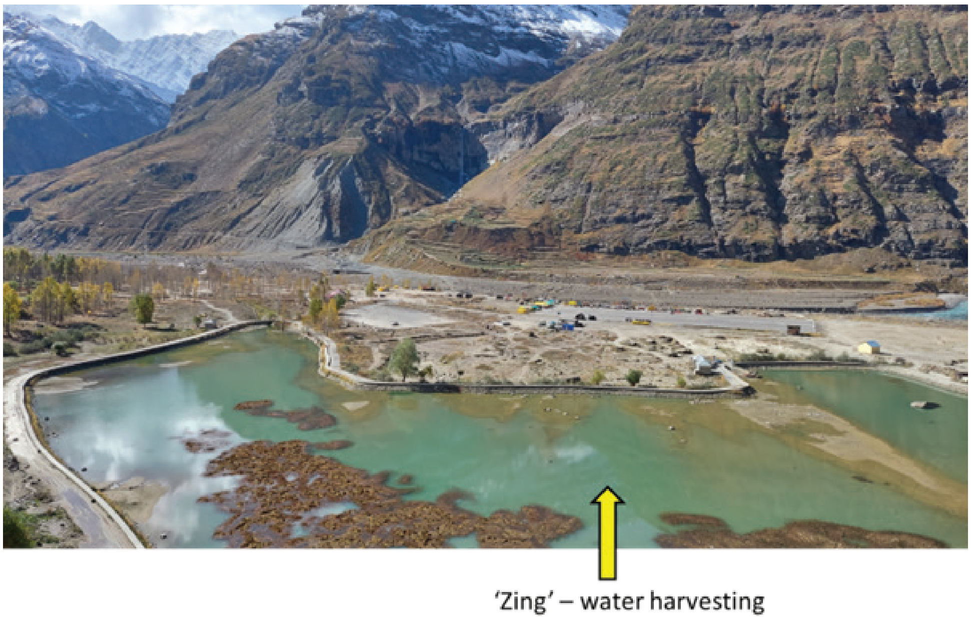
### 3.2.2 Reviving traitional water management systems in the Himalayas: the Zing and Kul systems

Traditional water management systems, such as the *Zing* and *Kul*, have been integral to the survival and sustainability of Himalayan communities for decades (Huda *et al.*, 2019).

The *Zing* system, prevalent in the cold desert of Ladakh, is a traditional water harvesting method that stores water from melted snow and glacial streams (see Figure 3). *Zings* are small, human-made ponds located near villages and fields, where water is stored during the brief summer months (Huda *et al.*, 2019). The stored water is used for irrigation during the short growing season. Assessments have shown that a single *Zing* can store up to 1 000 $m^3$ of water, providing sufficient irrigation for approximately 2 ha of land during the growing season. The successful implementation of the *Zing* system in Ladakh has led to significant improvements in agricultural productivity, with crop yields increasing by 30 to 40 percent in areas where this system is effectively managed. Moreover, the *Zing* system has helped to reduce the vulnerability of Ladakhi farmers to climate-induced water scarcity, ensuring a more reliable water supply for irrigation (More, 2021).

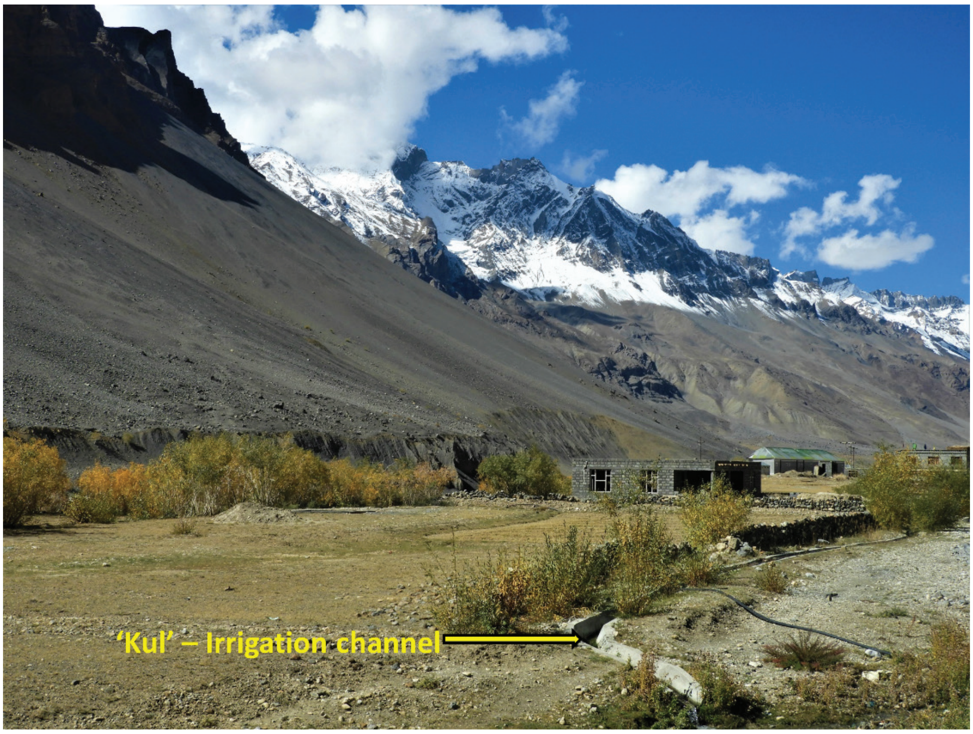
**Figure 3. A 'Zing' system in Lahaul district near Ladakh**



*Source:* Supdipta Das

The *Kul* system, another traditional water management practice, is found in the mountainous regions of Himachal Pradesh. *Kuls* are small, gravity-based irrigation channels that divert water from natural springs or streams to agricultural fields (see Figure 4). These channels, often several kilometres long, are meticulously maintained by local communities to ensure a consistent water supply throughout the year (Raina and Sharma, 2019). The *Kul* system can effectively distribute water to fields located up to 10 km away from the water source, with minimal loss due to evaporation or seepage. This system has been particularly successful in areas with limited access to modern irrigation infrastructure, enabling smallholder farmers to cultivate crops in otherwise arid and water-scarce regions. The *Kul* system has been credited with enhancing agricultural productivity and contributing to food security in Himachal Pradesh (Raina and Sharma, 2019; More, 2021). For instance, in the district of Kullu, the *Kul* system has supported the cultivation of high-value crops such as apples and vegetables, resulting in a 25 percent increase in household incomes.

**Figure 4. A 'Kul' system at Spiti valley in Himachal Pradesh**



*Source:* Supdipta Das

Despite their proven benefits, these systems face challenges in scaling up. Population growth, changes in land use and the impacts of climate change have put pressure on these systems, which now need modernization and adaptation (Huda *et al.,* 2019). Scaling up these systems requires a combination of technical, institutional and policy interventions. One of the key conditions for scaling up is the integration of traditional knowledge with modern water management practices. Modernization and adaptation of traditional water systems include improved storage techniques, such as using concrete or geomembranes to enhance durability and reduce seepage. Efficient water distribution is achieved by using polyvinyl chloride (pvc) pipes or underground channels to minimize water loss. Climate change adaptations involve creating artificial glaciers or '*ice stupas'* to store water for irrigation. Government and non-governmental organization (NGO) interventions have provided technical support and solar-powered pumps. Community-led management has introduced water user associations and smart water systems. Capacity building focuses on water management training, budgeting and participatory approaches that involve local communities in the planning, implementation and maintenance of water management systems (Huda *et al*., 2019). Farmers are also diversifying crops, shifting from water-intensive varieties to those requiring less water, such as fruits and vegetables.

Additionally, the provision of financial incentives and technical support from government agencies and NGOs is helping to facilitate the restoration and expansion of these systems. For example, the Himachal Pradesh Government's initiative to provide subsidies for the repair and maintenance of *Kuls* has resulted in a significant increase in the number of functional *Kuls*, thereby improving water availability for irrigation.

Reviving and scaling up the *Zing* and *Kul* systems in the Himalayas can significantly enhance water security and agricultural productivity. By integrating traditional knowledge with modern practices, and by fostering strong institutional support, these systems can be effectively scaled up to meet the growing water needs of Himalayan communities in a sustainable and resilient manner.

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A view of the mesmerizing Himalaya, India

© Sumanta Das, Malini Roy Choudhury, Sudipta Das

### 3.2.3 Local solutions for a greener, more resilient Anti-Atlas, Morocco

Village elders in the Siroua region of Morocco's Anti-Atlas Mountains remember when the hills were so thick with vegetation that they feared losing sight of their animals. Today, a combination of climate change and land mismanagement has left the hills largely barren, the plant life struggling. Traditional crops are increasingly difficult to cultivate, and sheep and goat husbandry are less and less viable.

For millennia the region has been inhabited by the *Amazigh* – or Berber – people, who possess a distinct cultural heritage and language. Farming and animal husbandry constitute the primary sources of sustenance. The Siroua breed of sheep provides exceptionally resilient wool, and the skills of shearing, spinning and weaving continue to be passed down through generations. But steadily declining precipitation and groundwater levels and excessive heat are converging to create an increasingly hostile environment. Farmers have had to adapt to shifting growing seasons due to climate change, which has also led to declining crop yields. The region's entire ecosystem has entered a downward spiral that threatens to impose a mass exodus on this people and its culture.

Migrations & Développement (M&D), a Franco-Moroccan NGO, works closely with local partners and government as well as citizens' associations to implement a new model of inclusive territorial development and revitalization. M&D's projects build on ancestral knowledge, combining it with modern agroecology practices. A small dam project is visibly transforming the landscape in Hloukte (513 inhabitants) where, for the first time, village farmland is now irrigated regularly. The dam, built from stones with simple construction methods, captures and holds rainwater at the bottom of a 220-ha watershed area. In parallel, the local people have planted some 300 000 fruit trees, which have helped to stabilize the soil, prevent runoff and revitalize animal and insect habitats. The area has since been designated a protected zone. The installation of water capture thresholds upstream in the watershed has also helped to stabilize the soil, reduce runoff and increase water infiltration. This has significantly reduced the quantity of solid particles flowing downstream. As a result, sedimentation rates in hillside reservoirs have decreased, extending their functional lifespan. The Siroua region is dotted with villages whose survival will depend on effective, collaborative and equitable water management. The Hloukte project will serve as a pilot initiative, and tools and assistance will be provided for duplication in other sites.

*Amazigh* women are typically responsible for managing household and agricultural tasks, including fetching water, which makes them particularly vulnerable to the impacts of climate change. Easier access to water enables them to spend more time on potential sources of income, such as agricultural production and wool crafts. Leadership training initiatives have led to improvements in their ability to bring these products to market. The programmes also provide inspiration for young girls, for whom local livelihood solutions are critical.

Meticulous observation is conducted on a bimonthly basis to monitor plant distribution and invertebrate populations – arachnids, myriapods, millipedes and crustaceans. This protocol provides consistent and precise data from designated locals in order to continuously monitor biodiversity diversification as an indicator of ecosystem health.

Olivier Hébrard, expert in agroecology and integrated water resource management and part of the project team explains: "It is essential to identify the most relevant indicators to monitor changes at the Hloukte watershed site. The indicators provide a clear picture of the erosion dynamics and vegetation changes in the area, enabling informed decision-making." (Olivier Hébrard, personal interview)

The numbers tell a promising story of environmental resilience. An August 2023 survey showed 52 percent vegetation coverage in managed basins compared with 10 percent concentrations in unmanaged basins. The data will support the pending application for Indigenous and Community Conserved Areas (ICCA) status. This formal recognition will strengthen Indigenous communities' efforts to protect their territories from the effects of climate change by legitimizing their traditional approaches to resource management. The ICCA status will strengthen support for conservation efforts and ultimately boost the resilience of the Indigenous communities to the consequences of climate change.

Shepherds in the Siroua region are facing significant challenges due to water scarcity and reduced vegetation, Morocco

© Migrations & Développement / Abdellah Azizi

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### 3.2.4 Artificial glaciers: innovations for water in Kyrgyzstan's mountains

With 94 percent of its territory consisting of mountains, Kyrgyzstan has been acutely experiencing the effects of climate change. Variations in temperatures are leading to unreliable precipitation patterns and more frequent peaks in temperature are causing aridity and drought, especially in mountain pastures, posing significant hurdles to the agriculture sector. Providing access to clean water for drinking, securing watering holes for farm animals on pastures, and ensuring sufficient water for irrigation are all pressing concerns, particularly in the southern regions, where summer precipitation is sparse, and winter snowfall is minimal.

In winter (from mid-November to mid-March), water sources are not used, and water flows downhill away from mountain communities. To increase the communities' resilience to weather anomalies, experts from FAO proposed the construction of 'artificial glaciers' in the remote pastures of Kyrgyzstan.

The construction of an artificial glacier requires the installation of an underground pipeline (at a distance of 2 to 3 km from the source) with natural water flow according to gravity and a vertical pipe about 15 to 20 m high. In the cold season, at subzero temperatures, the water from the pipe begins to freeze and slowly turns into a huge ice tower, so the artificial glaciers gradually accumulate and store water. The volume of water can reach several thousand cubic metres and can be adjusted depending on the water pressure, the planned irrigation area, as well as the needs of the community. During the first winter, the glacier contained more than 70 000 $m^3$ of ice.

In the spring and summer months, the mountain of ice slowly melts, providing residents with regular access to freshwater for irrigation, drinking and other domestic uses, benefiting numerous households and enabling livestock grazing.

FAO's efforts have yielded promising results, with more than 20 artificial glaciers now in place across Kyrgyzstan. The first ones were established in the Uzgen, Kochkor and Aksy regions of Kyrgyzstan. Others are planned in Batken region.

Many of these glaciers were constructed through community collaboration, showcasing local ingenuity and resourcefulness. For example, in the Kashka-Suu village, a communal effort involved 55 local people, with men involved in digging the canals where the pipes were buried and women, who formed a self-help group (SHG), cooking and organizing the meals. In addition, SHG members have learned about the benefits of this technology and have been instrumental in disseminating information and knowledge through their networks (peers, neighbours and relatives) and other local communities. The result of this approach has been to promote local development and social cohesion.

Each year, in April and May, rural farmers and their families, especially those located in the lower stretches of the rivers, suffer a shortage of irrigation water for the first watering of the season. This creates inequalities in access to water resources at a critical time, building tensions between villagers. It is precisely during this period that the artificial glacier begins to melt, thereby helping to resolve the problem of water shortages for drinking and domestic needs, as well as for watering livestock. In this way, artificial glaciers are not only helping to distribute water, but are also reducing conflicts between farmers over this vital resource.

*"Many took the idea of an artificial glacier as a joke",* says 63 year-old Manzura Orolbaeva, a woman living in the outskirts of Kara-Dobo village where the glacier was built. *"But the residents of the village of Kara-Dobo supported the initiative. If we do not water the gardens, everything dries up. We will have nothing to cover our expenses or to feed our cattle."*

The appeal of the artificial glacier solution lies in the simplicity of its low-cost construction and in its replicability, its suitability for implementation in remote areas, as well as in the lack of need for special training.

Local authorities have recognized the effectiveness of the artificial glaciers and plan to invest in further installations, using local funding sources. This integration of local knowledge and experience enriches climate change adaptation strategies and enhances the resilience of rural livelihoods.

## 3.3 Protected areas, forests, green cities

Mountains are among the most biodiverse areas on Earth. Building resilience depends on halting biodiversity loss and maintaining the ecosystem services provided by natural areas, including through protected areas. This is best achieved by approaches that integrate conservation objectives with social and economic objectives and recognize the multiple functions of mountain landscapes and the interests of different stakeholders.

Mountain forests cover 39 percent of global mountain area and grasslands. Forestry practices to support adaptation and resilience in mountains include approaches that promote and maintain the provision of goods and services from forests and trees, such as carbon sequestration, income, nutrient-rich foods, habitats for pollinators and wild species, microclimate control, water and nutrient cycling, soil erosion control and nitrogen fixation, while considering the complex and context-dependent interactions in the ecosystems, particularly forest-water interactions.

Of about 1 billion people living in mountain areas of developing countries in 2017, the number living in urban areas was 356 million (35 percent of the mountain population) (Romeo *et al*., 2020) Mountain people represent a significant proportion of the total global population that is exposed to the effects of climate change. In Latin America, Asia and in Africa cities with one or several million inhabitants are located in mountainous environments or at high elevations, and particularly in developing countries, informal and low-income settlements are common (Dodman *et al.,* 2022). Urban mountain areas and their populations are particularly significant in Latin America and the Caribbean, where many cities are developed in mountain highlands. In 2017, the region had the highest proportion of urban mountain people (112 million) – twice the region’s rural population (55 million) (Romeo *et al*., 2020).

Urban forests, public parks, street trees and green areas have an important cooling role and can play a significant part in buffering cities, settlements and infrastructure from climate hazards, as well as from the long-term changes due to climate change at multiple scales (IPCC, 2022). Sustainable practices for urban planning and development include investing in nature-based solutions to increase the resilience of urban mountain people.

Read more on the landscape approach to harnessing the potential of mountain biosphere reserves for biodiversity conservation, and on mountains and heritage-making.

Read more on transformational adaptation through forests and trees.

Read more on mitigation and adaptation in urban and peri-urban areas and the Green Cities Initiative.

Mountain ecosystems provide vital resources, Italy

under Subramanian

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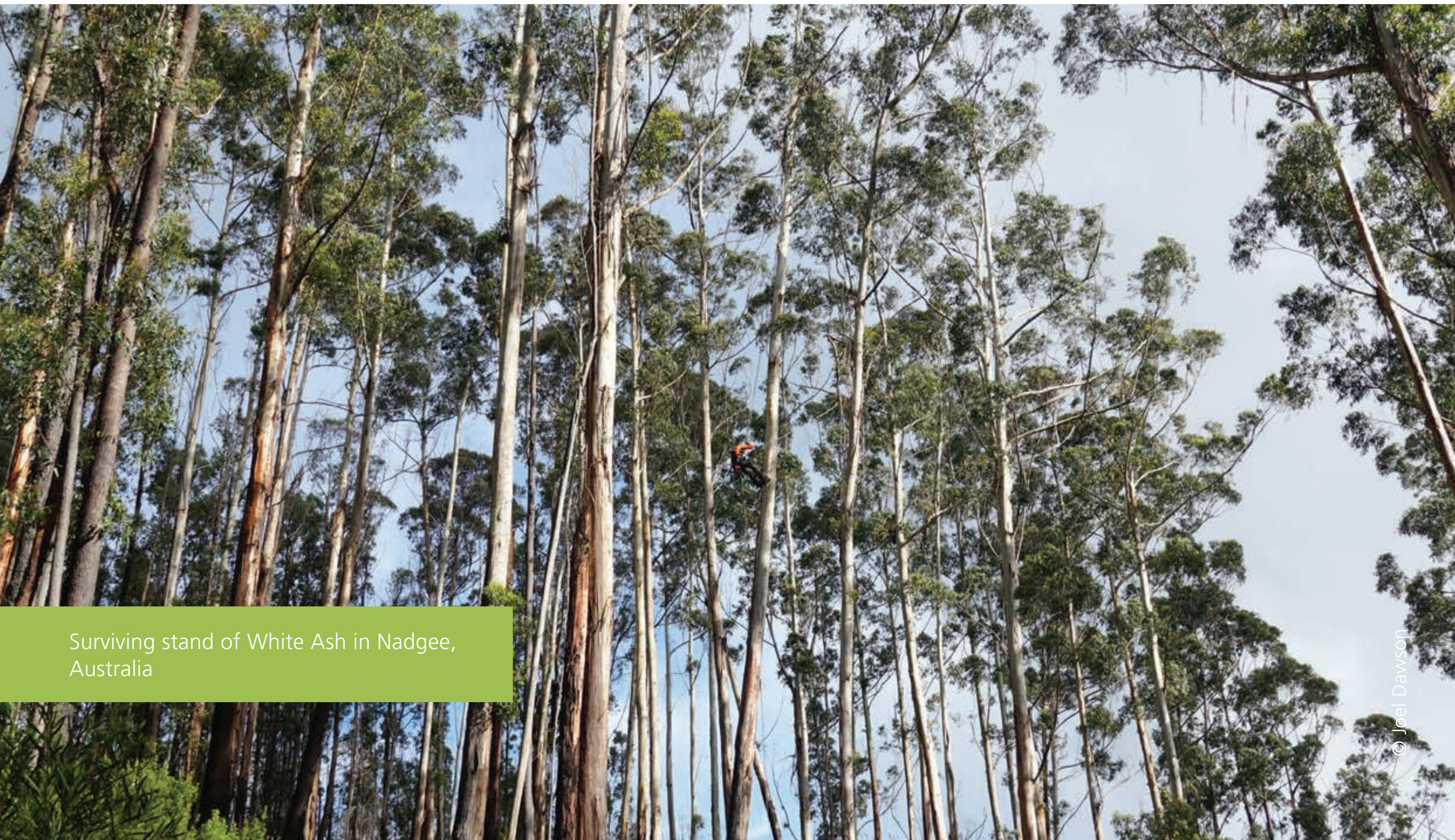
### 3.3.1 Safeguarding the future of Alpine ash forests in southern New South Wales, Australia

The Black Summer bushfires of Australia in 2019 and 2020 impacted substantial areas of obligate seeder eucalyptus species, primarily *Eucalyptus delegatensis* (Alpine ash) and *Eucalyptus fraxinoides* (White ash) in southern New South Wales (NSW). For both species, stand-level mortality in over half of their distribution in state forests has been observed. Regenerating seedlings in these species will not produce seed for at least 15 to 20 years. There is a heightened risk, associated with a changing climate, that future unplanned fire events will be more frequent and intense (McColl-Gausden *et al*., 2022). As a result, fires in the intervening period may impact the distribution and abundance of the species.

The Forestry Corporation of NSW manages around 2 million ha of forests for conservation and commercial timber production, including Alpine ash and White ash forests. It has embarked on a seed collection programme for these two species to mitigate the increasing risk of severe wildfires associated with a changing climate, potentially leading to local extinction of these iconic forests.

Alpine ash and White ash are ‘obligate seeders’, meaning that they regenerate only from seed, dropped in the aftermath of a wildfire. The weakness of this regeneration strategy is that the trees themselves die after exposure to even mild fire (Attiwill, 2002), leaving the stand vulnerable to further wildfire, which kills the regrowing trees before they are mature enough to set seed and continue the regeneration cycle. This results in a type of change, whereby the ecosystem fundamentally shifts from tall wet eucalyptus forest to dense acacia regrowth (Keenan *et al*., 2016). In such a scenario, ash trees would essentially be lost from the landscape.



Surviving stand of White Ash in Nadgee, Australia

© Joel Dawson

A seedbank for these species is being established to act as insurance against a key climate change risk – increased frequency of fires in the landscape. As a secondary benefit, the seedbank also mitigates against other risk factors that would affect forest regeneration and could be climate-driven, including pest and diseases.

These forests play an essential role in the identity of the Snowy Mountains region, a unique part of NSW that holds historic and ongoing importance for local communities. Protecting these forests, and ensuring their persistence following wildfire, is not only ecologically critical, but also important to the people of the Snowy Mountains.

In response to this risk, local Forestry Corporation staff, working with expert seed collection contractors, have identified areas and stands at risk and are also monitoring the forest for the presence and maturity of seed crops. Forestry Corporation commenced collecting seed from Alpine ash and White ash forests in 2024. Collection of seed is dependent on crop availability, and flowering events, although generally cyclical, can be influenced by climatic and environmental factors (Florence, 2004).

There will need to be continued commitment to checking that the seed collection programme aligns with available crops, ensuring collection across the distribution of the species to account for genetic variation.

Seed can be stored with minimal degradation to viability for approximately 10 years (Florence, 2004), but it will need to be replenished as stocks age and new seed crops become available. In the event of wildfires before stand maturity, this seed can be rapidly sown by aircraft to take advantage of receptive seedbeds, so as to maximize regeneration success.

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### 3.3.2 Sustainable management of Togo-Ghana Highlands based on Missahoé mountain forest ecosystem resilience development

The Togo-Ghana Highlands is a transboundary mountain range that plays an important role in the sustainable development of both African countries. Although these mountains are regarded as valuable hotspots in West Africa, they have not received adequate attention from stakeholders and are suffering from pressures and erosion that have prevented them from coping with climatic risks and hazards. Research and various field actions have since been undertaken in efforts to reverse the trend.

Missahoé and adjacent mountains, which are part of the Togo-Ghana Highlands, were targeted for pilot actions that could strengthen their resilience and that of local communities, and reduce climate-related risks. Such risks were reflected in the periods of drought that had dried up watercourses and dried out coffee farms during their flowering periods, as well as in frequent landslides and in thick fogs that settled over long periods and rotted the cocoa plants. There were also long periods of rain that set in and compromised the development of food crops.

In order to address the issues, an area of 120 ha of Missahoé mountain reserve was demarcated in 2002 to establish a special zone called the Zone Naturelle d'Intérêt Ecologique et de Développement de la Résilience (ZNIEDR). ZNIEDR is subdivided into three plots to encourage comparative studies and determine what elements need to be introduced in order to establish a normal and suitable ecological succession to achieve resilience. The studies have made it possible to: (1) determine the soil profile ; (2) make an exhaustive inventory of the fauna and flora; (3) monitor the biodiversity of the remaining vegetation; and (4) plan reforestation with high-altitude plants.

Field visit teaching resilience system, Togo-Ghana Highlands

© Jules Yawo Kouma Adjima

The site restoration process began with various training workshops to enable the full participation of local communities. Women's social capital was strengthened, enabling them to take part in plant production and planting. Other activities included the promotion of specific forest trees used to improve the energy needs of households, and income-generating activities.

Ten years later – after various monitoring exercises were conducted to determine any weaknesses in the project and to understand the basics of ecological stability of the area – a number of activities to improve the biodiversity conservation system were undertaken in collaboration with experts from the Universities of Togo and Ghana. Ponds were created for the reproduction of amphibians, dragonflies, aquatic insects and plants. Young people were trained in butterfly farming. The improved biodiversity accelerated the development of undergrowth, enhanced the microbial life of the soil to facilitate carbon sequestration, and consolidated all phases of the dynamics of vegetation recovery that restored the microclimate and improved rainfall patterns.

Traditional methods of attracting birds and animals and of rearing and harvesting mushrooms were widely promoted. This latter activity helped to avoid the use of agrotoxic products to propagate plant rhizobia. The combined use of traditional and scientific methods contributed to the success of the initiative. The now resilient ecosystems have started to provide their valuable goods and services once again and local communities have reconnected with their environment and set in place measures to protect the rehabilitated sites.

The innovative aspect of this initiative lies in the rational use of natural capital by applying both traditional and scientific knowledge, favouring a step-by-step progression towards adequate ecological succession, as well as the sustainable management of fallow land and the rehabilitation of biodiversity.

### 3.3.3 Setting the adaptation agenda for Patagonia's World Heritage Site, Argentina

The Northern Zone of Los Glaciares National Park in Argentina is particularly exposed to the impacts of climate change. The Argentine Institute of Nivology and Glaciology (IANIGLA) established the presence of 863 glaciers within Los Glaciares National Park, covering an area of 2 923 km$^2$. This UNESCO site is one of the world's major solid freshwater reserves. However, there are no climate change adaptation public policies in the area, nor any site-scale climate change vulnerability assessment. Moreover, proven climatic risks – such as glacial lake outburst floods – are not yet the subject of risk management policies. In addition, the local governance context is marked by significant information gaps, structural funding shortfalls, and challenges in accessing information of public interest.

In order to set the local agenda for climate change adaptation, a group of women scientists, managers and activists from IANIGLA and the NGO Boana joined forces with the International Association of Cryospheric Science.

Panoramic view of the town of El Chaltén, Argentina

© Antonella Rosselli

The approach of this working group is based on the use of climate change adaptation guidelines for protected areas – mainly Life Natur'Adapt, Life Eau & Climat and the Practical Guide for adaptation in World Heritage Sites – as local advocacy tools to build the case for climate adaptation.

In the village of El Chalten, community and protected area managers face the consequences of a lack of investment in basic infrastructures and tourism planning. In this context, climate change adaptation can be perceived as a low priority. Nevertheless, the use of adaptation guidelines as advocacy tools is enabling the working group to tackle this issue. By finding common ground between local priorities and adaptation practices, it has been able to create a local approach to adaptation that is perceived as useful. For example, most adaptation methodologies require investments in monitoring and data management in order to identify adaptation measures from structured datasets. In El Chaltén, a long-term issue is the lack of environmental information. Now, a two-pronged approach that takes into account the adaptation guidelines and local priorities has resulted in drawing up a strategy to address climate change that is rooted in the most urgent needs.

Moreover, the steps involved in these methodological guidelines can be transformed into concrete political and environmental demands, fueling local advocacy campaigns to conserve the value of this World Heritage site. When interpreted through local challenges, guidelines enable citizens to formulate demands and create advocacy strategies based on specific actions – such as inventories, climate projections or risk management. Moreover, guidelines facilitate the identification of governance practices and stakeholder groups. In this context, climate change adaptation guidelines are helping to tackle local priorities that are not climate-related, while mainstreaming the adaptation focus, and can therefore contribute to closing the adaptation gap between mountain territories.

In El Chaltén, the implementation of climate change adaptation guidelines has been entirely led by women. In 2024, other crucial women-led advocacy has proved successful in addressing a critical health issue linked to the development of antibiotic-resistant bacteria within the waters of the protected area. Nevertheless, the lack of data on links between gender and the environment (including women's role in mobilization, environmental lawsuits and agenda-setting) has proved a limitation in understanding the socioenvironmental dynamics. In order to foster climate change adaptation, it is important to understand and support the work of women building linkages between local communities and international organizations. In the Northern Zone of Los Glaciares National Park, women's leadership is paving the way towards the beginning of climate change adaptation in a strategic World Heritage Site.

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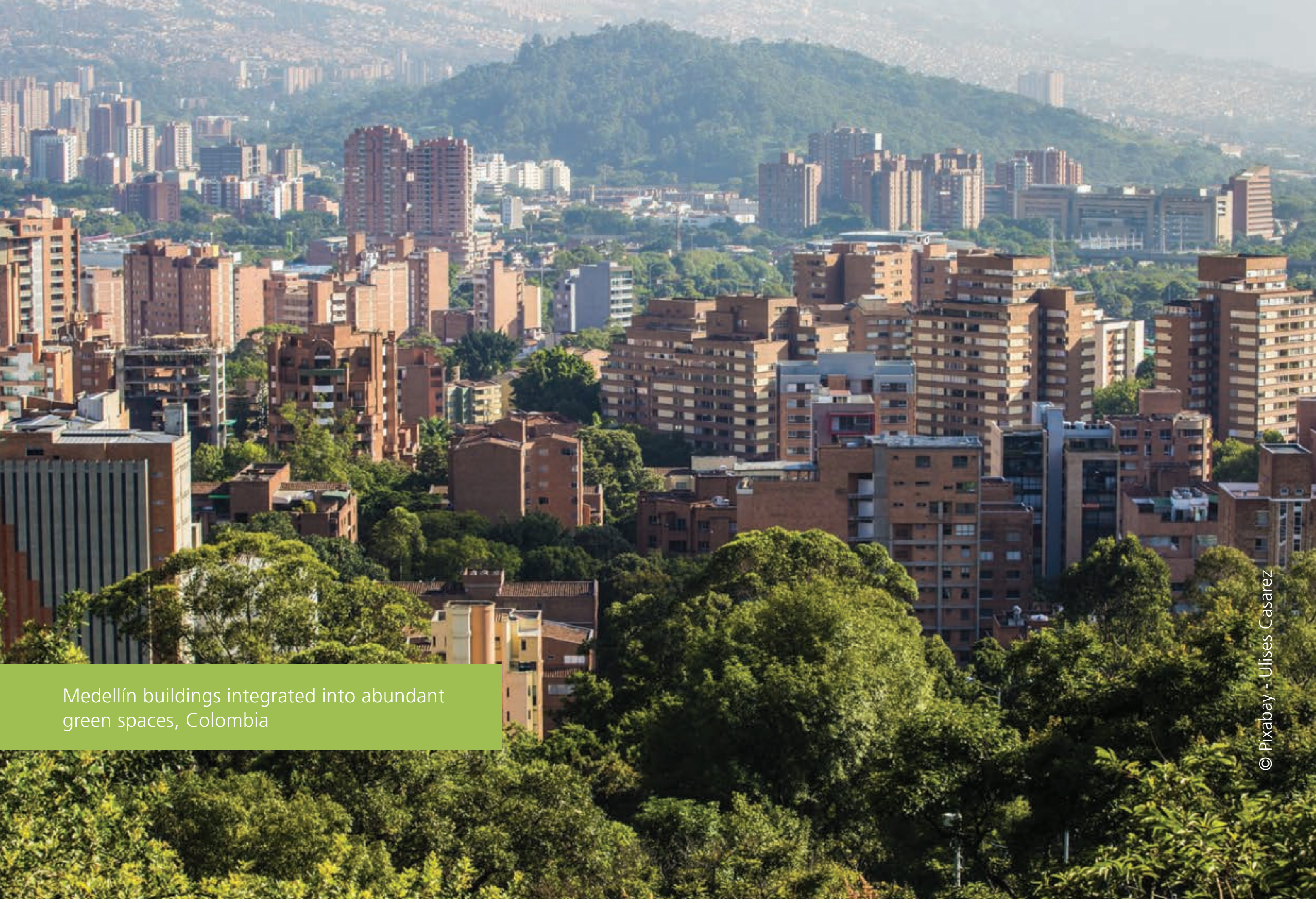
## 3.3.4 Climate-resilient social urbanism in Colombia: 'Medellin's Miracle'

Medellín is located in the Aburrá Valley in the Andes at an elevation of around 1 500 m a.s.l., surrounded by mountains. This stunning yet challenging location has made the city susceptible to the impacts of climate change, particularly to risks of landslides and flooding.

Starting in the early 2000s, the city has implemented urban regeneration efforts, focusing particularly on underserved communities. The strategy has included a social urbanism approach and the use of Integrated Urban Projects, which have provided high-quality urban spaces to informal settlements and contributed to the construction of parks, libraries, social housing, sports, health and educational centres in the periphery of the city (Meninato and Marinic, 2024; Naef, 2020). The introduction of the Metro Cable has connected underserved neighbourhoods with the rest of the city transport network. More than 50 000 trees of 46 species, including 327 native trees, were planted in the Moravia macro-urban intervention alone (Collado and Wang, 2020), mitigating the urban heat island effect, improving air quality and restoring the natural water cycle.



Medellín buildings integrated into abundant green spaces, Colombia

© Pixabay - Ulises Casarez

Medellín's residents have actively participated in choosing the projects to be funded and in ensuring that their needs and priorities were addressed. The Green Corridors initiative, launched in 2017, has created microclimates that help to regulate urban temperatures and mitigate the heat island effect, providing shaded areas and making the city more accessible for walking and cycling.

Along the Avenida Oriental, once one of the most polluted streets in Medellín, 2.3 km of pavements were replaced with gardens, significantly reducing particulate matter levels (SEforALL, 2021). These efforts have led to the return of 30 butterfly species and numerous bird species (Stancliffe Bird, 2022).

The "Greener Medellín for You" programme trained about 100 residents from disadvantaged backgrounds, in collaboration with experts from Medellín's Joaquin Antonio Uribe Botanical Garden, to become gardeners and planting technicians (C40, 2019). By 2021, their efforts had contributed to the planting of 2.5 million plants and 880 000 trees and palms across 30 corridors, covering 65 ha (SEforALL, 2021).

Medellín has also addressed food insecurity through the City Region Food Systems Programme, jointly with FAO and the Resource Centres on Urban Agriculture & Food Security Foundation (RUAF). By encouraging residents to participate in food production, Medellín has reduced its reliance on informal and vulnerable food distribution networks, improving food security (FAO and RUAF, 2019), especially during crises such as the COVID-19 pandemic.

The city's Climate Action Plan (2020–2050) includes efforts to improve energy efficiency in buildings by adopting green roofs and vertical gardens, which not only mitigate climate impacts, but also enhance the city's aesthetic appeal (Municipality of Medellín, 2021).

Medellín's ability to reinvent itself is a powerful story of resilience, innovation and community-driven change. The city has emerged from its complex past through focused efforts on urban renewal and support for disadvantaged communities. These efforts have earned Medellín international recognition in global initiatives such as C40 and 100 Resilient Cities, while also attracting tourists eager to witness its transformation. This has further strengthened the city's commitment to revitalization, creating a virtuous cycle of continuous improvement and establishing Medellín as a global model for climate and social resilience.

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Group to receive training on farming by FAO, Rwanda

© FAO/Petterik Wiggers

## 3.4 Social business entrepreneurship and sustainable investments in mountain value chains

In mountain regions, entrepreneurial efforts often focus on preserving biodiversity, protecting fragile ecosystems and promoting sustainable tourism. However, social and environmental responsibility approaches can also offer an opportunity to address the specific challenges that mountain communities face, while also generating economic benefits.

Social businesses worldwide are based on addressing social or environmental problems while achieving financial sustainability, reinvesting the profit in expanding and improving the business or creating new social businesses. Strengthening local producers' marketing knowledge and value chains can add value to mountain products by highlighting their benefits in terms of biodiversity preservation, gastronomic richness and their environmental role.

In many mountain areas, as men migrate to lowlands or abroad in search of better income, investments targeting and prioritizing rural women can enhance their employment opportunities and access to and control over natural and economic resources.

Targeted commercial strategies, labelling and geographical indications can communicate and promote the linkages between food, culture and territory.

Recipes with local mountain products represent a broad patrimony for cooks and chefs that recognize, conserve and simultaneously allow mountain territories to evolve, leveraging their economic potential.

The ecotourism, community-based tourism and agritourism sectors are intrinsically linked to local food systems and offer valid opportunities for sustainable mountain development strategies (such as adopting year-round tourist activities in response to snow cover loss). Case studies described in this chapter provide concrete examples of how support for social business entrepreneurship can make a difference.

Despite the challenges linked to remoteness, climate change impact and poor infrastructure development in mountain regions, social business entrepreneurship and sustainable businesses offer promising opportunities for economic development and environmental protection. By supporting their social businesses through capacity development and funding, entrepreneurs can create sustainable livelihoods and contribute to the well-being of mountain communities and environments.

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### 3.4.1 Co-creating a sustainable future in the mountain destination of St. Corona am Wechsel, Austria

Specific topographic, climatic and ecological features, combined with social, political and economic conditions lead to great diversity among mountain regions. Mountains' natural and cultural appeal attracts tourists, and ski tourism in particular has become an economic mainstay for communities in the European Alps (Federal Ministry of Labour and Economy, n.d.; Domaines Skiables de France, 2023; Eurostat, 2024). However, problems such as high land prices (Cró and Martins, 2023) and challenges posed by climate change (Hock *et al.*, 2019; Steiger *et al.*, 2022) are increasingly calling these established economic models into question.

The Interreg Alpine Space project TranStat (Interreg Alpine Space, 2021) is actively addressing the future of destinations in the European Alps.[5] The project team identified stakeholders and organized workshops with them in Saint Pierre de Chartreuse (France), Megève (France), Vals (Switzerland), Chiesa in Valmalenco (Italy), Maniva Ski (Italy), Großes Walsertal (Austria), St. Corona am Wechsel (Austria), Kranjska Gora (Slovenia) and Rogla (Slovenia). The workshops highlighted that while destinations face the same megatrends, local parameters are specific. Consequently, the main challenges range from high traffic volumes to a lack of prospects for young people to snow insecurity. Based on the situation, participants create desirable future visions and transition pathways.

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[5] Although the term 'destination' is used, the places are not reduced to ski tourism, but are considered more holistically. The participating destinations do not correlate with municipalities because Maniva ski is on a mountain pass that separates two municipalities. The term 'destination' is used because ski tourism is present in all the participating places, albeit to varying degrees.

View of the tourism destination of St. Corona am Wechsel, Austria

© St. Corona am Wechsel – Wexlarena/StefanWallner

St. Corona am Wechsel, located in the easternmost Austrian Alps, serves as a role model because it has already undergone a transition process. Since the 1990s, it has become increasingly difficult to guarantee sufficient snow cover in this low-lying ski area. Due to warmer temperatures, the natural snow cover has become insufficient, and producing and sustaining the necessary amount of snow barely possible and too costly. In 2014, the ski lift owners decided to dismantle much of its infrastructure and to reforest the former ski slopes. Today, alternative activities are offered, with an emphasis on family activities (Wexl Arena, n.d.). The existing infrastructure is used innovatively: In summer, ski lifts carry cyclists, and the reservoir pond is used for stand-up paddling. Not only have the mountain bike trails been expanded, but the mountain bike season has also been prolonged. The seemingly distinct seasons of winter and summer are becoming blurred, and it is no surprise to see downhill mountain bikers in March. However, for each mountain destination, specific contexts and challenges need to be understood in order to identify socioeconomically and ecologically sustainable solutions.

The transition of St. Corona was driven by persons with a vision that was radical and not always popular, but which was adapted to the topographic and climatic conditions of this mountain location. The involvement of the federal state of Lower Austria, which is supporting sustainable regional economies, facilitated the transition in financial terms.

Experiences from St. Corona provide some important lessons, which the TranStat project considers in its participatory approach. Involving local people in decisions over their own future has the advantage that people can develop trust and a sense of ownership (Voorberg *et al*., 2014; Bentzen, 2022; Guittard *et al*., 2024). Moreover, the solutions encompass a range of perspectives and are sustainable in each specific context (McCrory *et al*., 2022).

Nevertheless, some stakeholders (such as ski lift operators) have the power to decide on crucial issues on their own. Therefore, depending on the local situation, a mix of public meetings attended by more than 100 people from different backgrounds and participatory workshops with comparatively few but powerful stakeholders, are taking place in TranStat.

The TranStat project explores the possibilities of co-creative processes in real-life settings. Pressing problems can lead to an awareness of the need for sustainable solutions, supported by a high level of participation.

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### 3.4.2 Emerging risks – mountain guides adapting

In 2021, the board of the International Federation of Mountain Guides Association (IFMGA, 2023) identified the emergent risk of climate change as a direct threat to the mountain guide profession. The damage to mountain ecosystems through the impact of climate change, for example through the thawing of permafrost, is leading to the loss of historical climbing routes, which in turn impacts the social and economic fabric and cultural heritage of mountain communities. These changes have implications for future generations.

A solutions-oriented approach with education and strategies for adaptation was established with initial outreach to other professional organizations, mountain stakeholders and partners such as the Zero Water Day Partnership. The IFMGA Technical Commission formed a working group to build a multinational curriculum: Sustainable Mountain Guiding and Emerging Risk, which can be locally adapted and used by 27 IFMGA member associations around the world in their training schemes. This will support instructors, prepare young guides for managing and adapting to mountain hazards with skillsets based on science, local knowledge and best practices for sustainable mountain guiding. A train-the-trainer programme will build capacity within national associations and provide a feedback loop for evaluation and quality improvement.

The concept of sustainable mountain guiding (SMG) aims to ensure that adaptation, mitigation and resilience efforts across the federation are coordinated and consistent, are framed within sustainable mountain development, and are aligned with sustainable mountain tourism strategies at local, subnational, national, regional and global levels (IFMGA, 2023). The Swedish Mountain Guide Association has adopted a step-by-step approach to formally incorporating sustainability across its organization, with the primary goal of establishing it as “an everyday activity”, including carbon footprint tracking of the association’s activities, as well as banning ski wax made of harmful per- and polyfluoroalkyl substances PFAS among members (Swedish Mountain Guide Association, 2023).

The SMG curriculum will strengthen the role of mountain guides as stakeholders and educators, with potential opportunities to diversify their work with public engagement. The UNESCO World Heritage Swiss Alps Jungfrau-Aletsch hosts education sessions for sustainable mountain development and offers schoolchildren excursions onto glaciers with an IFMGA mountain guide (UNESCO, 2023). The Association of Canadian Mountain Guides provides guides with tools for assessing the impact of their professional practices, as well as open spaces for conversations about how to reduce impact and relate these issues to their clientele. HeliCat Canada is leading the way with its Sightlines 2030 and its goal to see the mechanized skiing industry become carbon neutral by 2030, which will require the collective effort of guides, clients and operators alike (HeliCat Canada, 2023).

Mountain guides have a central role to play in promoting resilient and sustainable lives and livelihoods for all mountain inhabitants. The French *Syndicat National Guides de Montagne* publication on common hazards in mountain summers is anchored in local ecosystem knowledge and is part of a larger project

Swiss Mountain Guides with children crossing a glacier, Switzerland

Janosch Hugi

'*Regard d'altitude*' (Syndicat National des Guides de Montagne (SNGM), 2023). It engages stakeholders, including local government representatives, mountain guides, mountain hut wardens, national park staff members and university research partners. The project demonstrates an integrated approach to sustainable mountain development, while monitoring the natural risks generated by climate change through mountain guides, which can inform policy and multisectoral financing and investment.

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### 3.4.3 Social business entrepreneurship in Mongolia

The Mongolian Wool and Cashmere Association (MWCA) was established in 1993 to address inefficiencies in Mongolia's traditional cashmere and wool industry. The organization focuses on transforming the sector into a sustainable, environmentally friendly and socially equitable industry. By doing so, MWCA has contributed significantly to the livelihoods of rural Mongolian communities, especially herder families, while tackling climate change adaptation through sustainable practices in the textile value chain.

The association operates in the textile sector, with a vision of revolutionizing the cashmere and wool industries. Historically, the high volume of cashmere wasted during production created economic and environmental concerns. MWCA addresses these challenges by implementing a circular supply chain approach, recycling waste yarn and old garments to minimize waste and achieve zero-waste production. This not only reduces the industry's environmental footprint, but also aligns with broader goals of climate change adaptation by promoting resource efficiency and reducing the need for excessive raw material extraction.

Collaborating with herder cooperatives, MWCA works to ensure that herders adopt sustainable grazing techniques, protecting the fragile ecosystems that they rely on for their livelihoods. Furthermore, MWCA improves herders' welfare by fostering better animal care practices and ensuring that these are passed down through the cooperatives, contributing to the long-term resilience of the communities.

The association has created more than 10 000 jobs for women and supports 180 000 herders across rural Mongolia. By offering fair wages and decent employment practices, it is helping to build resilient communities capable of withstanding the socioeconomic pressures of climate change (Yunus Environment Hub, 2024).

Under the Business Incubator and Accelerator (BIA) for Mountain and Islands programme, MWCA aims to establish the first designers' hub for small and medium-sized enterprises in Mongolia's textile sector. This initiative seeks to embed sustainable production practices throughout the industry, from herders to manufacturers. The overarching goal is to strengthen climate-resilient strategies, including promoting sustainable grazing methods, improving herder livelihoods, and enhancing animal welfare. MWCA's work is essential in creating an adaptive framework that can withstand the growing pressures of climate change in Mongolia's mountain areas.

The BIA, which is implemented by the Mountain Partnership Secretariat at FAO and supported by the GEF Small Grants Programme and UNDP, plays a crucial role in empowering organizations like MWCA. The BIA programme focuses on supporting mountain and island communities, which are particularly vulnerable to the impacts of climate change, by fostering innovative entrepreneurship in agricultural and textile value chains.

The programme, implemented by the Yunus Environment Hub (Yunus Environment Hub, 2023a), offers critical support and expertise to MWCA in

GOLDEN MOUSE
HACKATHON

Students from fashion and design schools and wool and cashmere factories collaborated at the MWCA Hackathon, an initiative of the MWCA's designer's hub. In this photo, T. Bayarmaa presented an innovative product titled "Dream recall" crafted from reborn cashmere, blending artistry with sustainability, Mongolia

© Yunus Environment Hub

capacity development, business strategy and value chain integration. The programme provides mentorship, helping MWCA to refine its business model to align with sustainable practices and climate resilience goals. BIA's support also assists MWCA in scaling its operations, improving commercialization strategies, and navigating market access challenges, ensuring that the organization's impact is both sustainable and scalable.

With the support of the BIA programme, MWCA is positioned to continue leading the way in eco-friendly textile production, offering a model for other organizations seeking to address the dual challenges of economic development and climate adaptation in mountain regions.

To foster a more resilient and inclusive economic environment, it is crucial to create funding mechanisms such as revolving funds or targeted loans specifically designed for small-scale mountain producers. These financial tools will increase access to capital, enabling producers to scale their operations, invest in sustainable practices and innovate their products and services.

Removing barriers related to market access is also crucial, in order to build connections into broader value chains (Yunus Environment Hub, 2023b). Creating coalitions can facilitate the flow of knowledge and economic resources needed to scale the activities. By building resilient value chains, promoting sustainable practices and improving local livelihoods, MWCA sets a powerful example of how product-driven initiatives can contribute to climate resilience.

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### 3.4.4 New career paths – from forest work to ecotourism in China

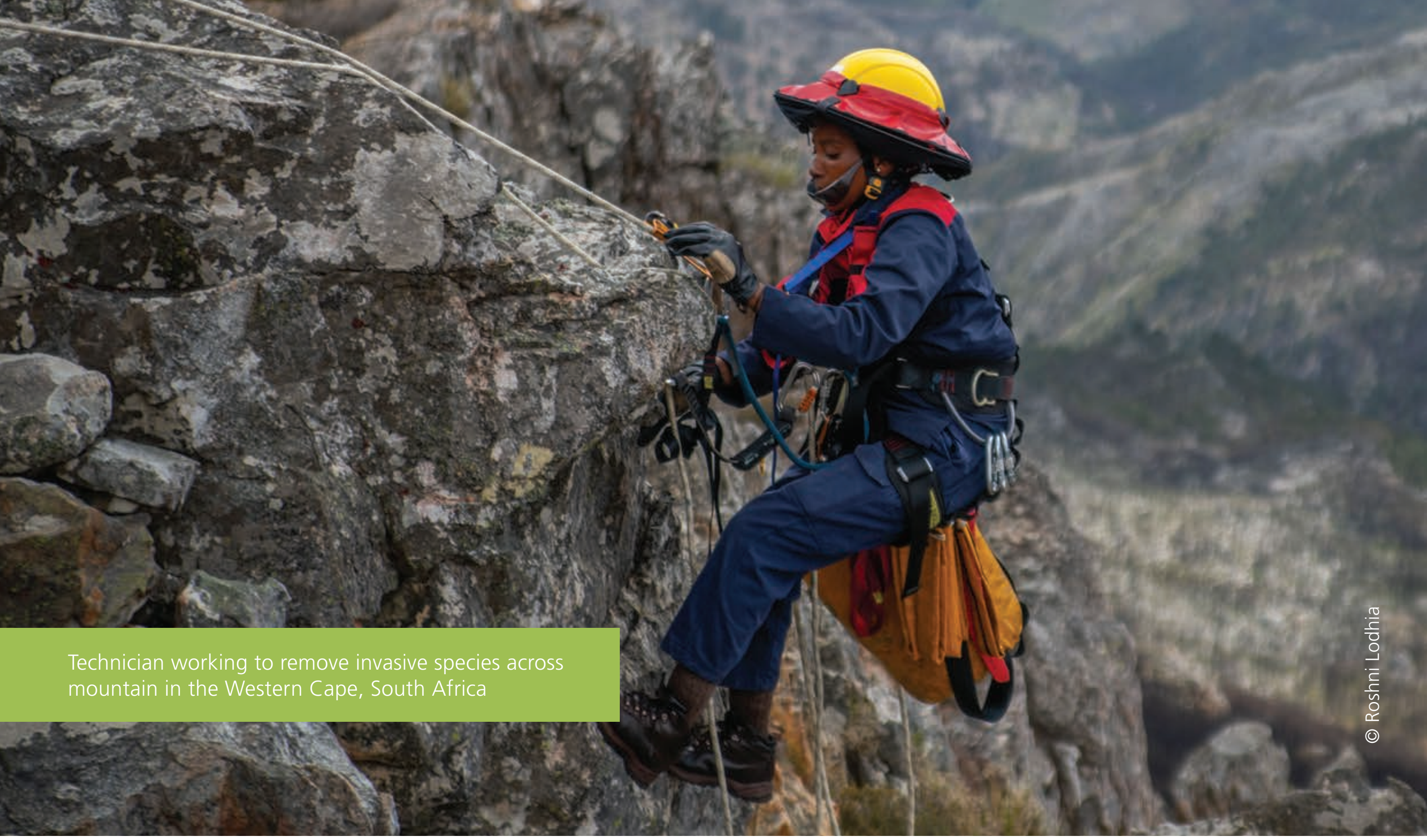
The Changbaishan World Biosphere Reserve (Changbaishan WBR) is highly sensitive to climate change due to its unique geographical location, climate characteristics and ecological resources, and the impact is particularly pronounced here. The surrounding communities rely primarily on forestry for their livelihoods, but deforestation has had adverse effects on the local ecosystem. In 2015, the state launched the Natural Forest Resource Protection Project (Tianbao Project), which led to a comprehensive ban on commercial logging in key state-owned forest areas in northeast China. As a result, forestry workers who had spent their lives working with timber were forced to explore new career paths.

Zhang Haiming, the owner of Veteran Inn, was once a soldier who, after retiring from the army, became a forestry worker at Huangsongpu Forest Farm, engaged in traditional forestry production. He started his hospitality business in 2016. Initially, the transition was challenging, but with the support and assistance of the Forestry Bureau leadership, he successfully navigated the transition period and significantly increased his income. He is optimistic about the future development, believing that a customer-oriented business approach and policy support from the management will ensure a stable income. He is also exploring new marketing channels, such as joining online travel platforms and live streaming.

Camellia Farmhouse, established around 2009, is a family-run inn that offers food and accommodation. The owner, DAI Hong, is a woman forestry worker, and older generations of her family have also worked on the forest farm. Huangsongpu Forest Farm was originally a main logging bureau, where logging and planting occurred simultaneously. However, following implementation of the Tianbao Project, the forest was closed for regeneration, with only planting allowed and all logging banned. This greatly improved the forest ecosystem, and the pristine natural environment around the inn has provided an enjoyable experience for guests. Recognizing the tourism potential of the biosphere reserve, DAI Hong's family members have all participated in her entrepreneurial venture, helping to smooth the transition and expand their business in line with tourist demands.

Huangsongpu Forest Farm covers a total area of 13 407 ha, with forest coverage of 97.14 percent. It is the main access point to the northern scenic area of Changbaishan, which is located within the Changbaishan WBR, and is only 6 km away by car. The forest farm has 153 households with 287 permanent residents. Since the implementation of the Tianbao Project and the comprehensive logging ban in 2015, the number of guesthouses in the area has increased from 3 in 2001 to 30. Many forestry workers, with the support and assistance of local management, have successfully transitioned to new careers by opening guesthouses or restaurants, significantly increasing their income by providing services to visitors.

In response to the economic transition of Huangsongpu Forest Farm and local tourism demand, the management of the Changbaishan WBR proposed targeted support policies. In addition to the existing large visitor centre, a smaller one has been set up in Huangsongpu to facilitate access for visitors to the northern scenic area and the town. During the peak summer tourist season, Huangsongpu receives about 32 000 visitors and the income of the forest farm workers has increased. The expansion of the Huangsongpu model has been driven by the favourable ecological environment, the development of ecotourism, supportive local policies, and the cooperative relationship between the reserve and surrounding communities, who are benefiting from this sustainable tourism development.



Technician working to remove invasive species across mountain in the Western Cape, South Africa

© Roshni Lodhia

# 3.5 Building resilience to manage disaster and climate risk for mountain people

Disaster risk reduction and management and adaptation in mountains are closely linked. Several measures can be implemented at farm and landscape level to reduce disaster and climate risks and the underlying vulnerabilities of mountain people, especially rural communities, and the agrifood systems on which they depend (FAO, 2023a).

Ecosystem-based approaches have been proved to reduce multiple risks, while at the same time increasing agricultural production and generating socioeconomic and environmental benefits. As described in previous sections, they involve a range of strategies, including conservation agriculture, agroforestry, grazing optimization, improved water management and drainage, using local crop varieties and varieties that are more tolerant to heat or saline conditions, enhancing crop diversification and agrodiversity, soil and ecosystem restoration, forest and landscape restoration, the construction of natural barriers to mitigate landslides, and integrated fire management.

In mountain areas, these practices help to enhance ecosystem resilience to hazards such as landslides, floods and avalanches by stabilizing soils, managing water flows and protecting biodiversity. Anticipatory actions are fundamental, including those that build on local knowledge of disaster risk and communities' risk perception and existing risk preparedness measures. Gender-responsive, community-based multi-hazard early warning and early action systems are the foundation for anticipatory actions.

Transboundary governance and inclusive planning that integrates both local and scientific knowledge are essential for monitoring and managing risks. These approaches require integrating local knowledge, especially Indigenous knowledge, with scientific data and ensuring community participation in planning and decision-making (Swiderska *et al*., 2018; Adler *et al*., 2022; IUCN, 2024).

The effectiveness of these strategies is limited by socioeconomic constraints and the fast pace of climate impacts, which threaten to outpace current adaptive efforts (Adler *et al*., 2022; Swiderska *et al*., 2018).

Specific measures can also be taken to enhance resilience at the societal level. These include risk-informed and shock-responsive social protection systems and insurance schemes, including climate and disaster risk insurance to protect livelihoods (FAO, 2023b).

Read more about addressing gaps and challenges related to loss and damage in agrifood systems.

Read more on systemic disaster risk reduction in mountains.

Read more on FAO's guidelines.

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### 3.5.1 Disaster risk reduction and green development in mountain areas of China

Climate change has made mountain areas more prone to various kinds of natural disaster, and often the areas with high climate risk are also those with the lowest socioeconomic development (Cui, 2014). Achieving synergy between disaster risk reduction and socioeconomic development can save valuable resources, thereby offering a key solution to supporting high-quality development in mountain areas.

In China, the first demonstration zone for this synergy mode of disaster risk reduction and green development (Li *et al*., 2023) is the Reshui River basin. Measuring about 163 $km^2$ and located in Xide County, Liangshan Yi Autonomous Prefecture, Sichuan Province, it is well known for its frequent flows of debris and widespread poverty (Cao *et al*., 2016). The initiative has been undertaken in collaboration with experts in geotechnical engineering, disaster risk management and regional development, and was supported by local governments, communities and residents. The main practices included the following (see Figure 5):

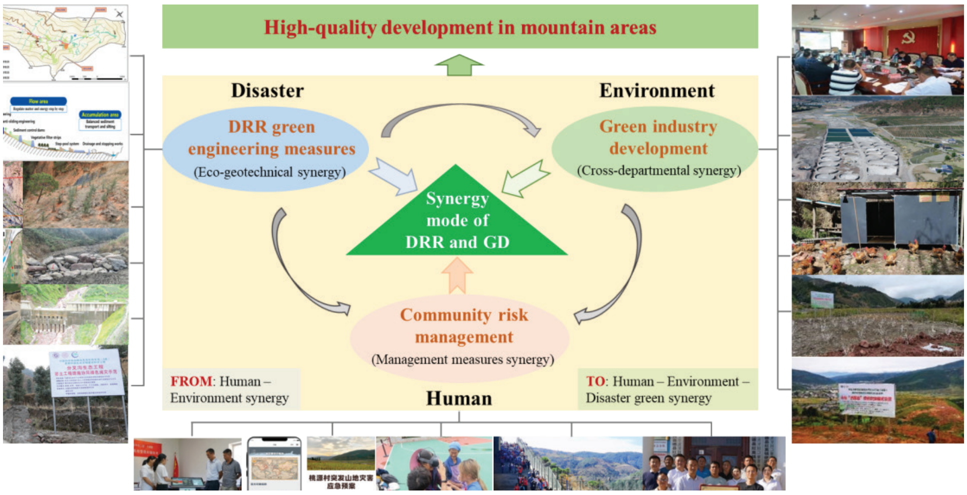
- Based on the innovative "Human–Environment–Disaster" green synergy theory in disaster prone areas, this initiative proposed a novel synergy mode of disaster risk reduction and green development and applied this to the regional development planning of the demonstration zone.
- A variety of novel technologies and models were developed for green disaster reduction, green industry development, community risk management and the related policy mechanisms for promoting synergies between disaster mitigation and green development in the demonstration zone.
- Disaster education and training activities were carried out for local residents, based on virtual reality technology, especially for primary and secondary school students, to enhance their disaster prevention awareness and capabilities.

After five years of efforts, between January 2019 and December 2023, the following results were achieved:

1. The overall appearance of the demonstration zone was completely transformed from the original debris flow waste-shoal landscape to a lush mountain with clear water (see Figure 6).
2. Due to support given to the green disaster reduction demonstration projects, no further natural disaster incidents have occurred.
3. More than 60 ha of debris flow waste-shoal land were developed as high-standard farmland and a high-efficiency aquaculture production base.
4. All nine villages within the demonstration zone were freed from poverty ahead of schedule, and the average annual income of local households increased 1.7 times.

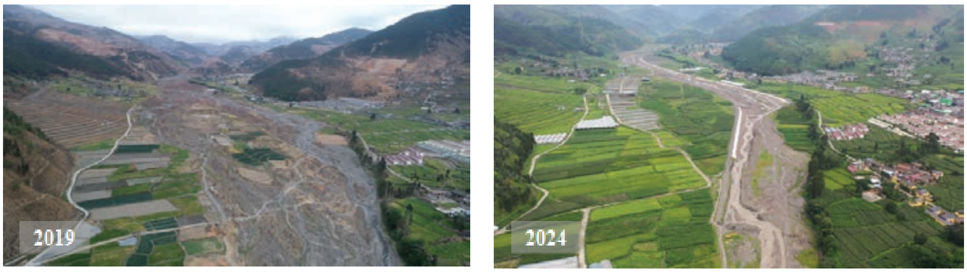
5. Taoyuan village became the first ‘National comprehensive disaster-reduction demonstration community’ of the Liangshan Yi Autonomous Prefecture. More than 8 000 local farmers and students benefited from disaster education and emergency drill activities, which significantly improved their disaster awareness and disaster prevention capabilities.

**Figure 5. “Disaster–Environment–Human” green synergy theory and its application in the demonstration zone**


High-quality development in mountain areas
Disaster
Environment
DRR green engineering measures
(Eco-geotechnical synergy)
Green industry development
(Cross-departmental synergy)
Synergy mode of DRR and GD
Community risk management
(Management measures synergy)
FROM: Human – Environment synergy
Human
TO: Human – Environment – Disaster green synergy
Flow area
Accumulation area
桃源村突发山地灾害应急预案

*Source:* Authors’ own elaboration

**Figure 6. Comparison of the overall appearance of the demonstration zone before (2019) and after (2024) construction**



*Source:* Ming Li

The core idea of the synergy mode of disaster risk reduction and green development has been documented in the *Comprehensive land consolidation planning in Anning River basin, Sichuan Province (2022–2035)*. Attempts are now being made to replicate this approach to other mountain areas with medium to high levels of natural disaster risks in China. .

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### 3.5.2 Climate resilience in rural landscapes of Colombia

Floods, droughts and high temperatures are the main threats to the rural community of Copacabana in Antioquia; added to this is loss of habitat and plant cover due to change of use in mountain ecosystems. For two years, the Colombian Red Cross has implemented actions to reduce climate risks and the humanitarian consequences of climate change, through the implementation of nature-based solutions and protection of the tropical forest.

The overall objective of the project *Resilience to Floods* and *Climate Resilience* is to reduce the humanitarian consequences and the effects of climate change in the community of Copacabana-Antioquia. To achieve this, it was necessary to: 1) link the communities to protect rural landscapes; 2) improve food security for the vulnerable populations settled there; and 3) promote adaptation measures to climate change, with a focus on flood risk.

The results of the intervention have contributed to improved living and food security conditions through the following:

1. The implementation of an 84 m² greenhouse, for the production of 10 000 seedlings of *Inga edulis* (Fabaceae), *Guamo Trichanthera gigantea* (Acanthaceae), *Nacedero Guadua angustifolia* (Poaceae), *Guadua Cecropia peltata* (Urticaceae) and *Yarumo* for protection of the rural landscape and water sources, to reduce the risk of rapid flooding. Through the construction of the greenhouse, the project seeks to establish a scalable nature-based solution to reduce flood risk, using hydro-regulating species. These plants are precursors in the process of plant succession and their root system, both deep and fibrous, has a high density that contributes to soil retention and stabilization. In addition, their leafy canopy facilitates rain interception, reducing erosion and improving flood buffering capacity.

2. The community-led installation of a 100 m² farm to cultivate edible plants such as lettuce (*Lactuca sativa*) and radish (*Rhaphanus sativus*), a common pairing where radish's allelopathic substances protect lettuce from pests, along with long onion (*Allium fistulosum*), coriander (*Coriandrum sativum*) and spinach (*Spinacia oleracea*). These plants were selected for their low-nutrient needs, shallow roots and rapid growth. Each species, through its distinct foliage, may influence temperature, humidity and carbon dioxide capture. The farm is expected to produce approximately 20 plants per m².

Training of volunteers to strengthen institutional and community capacities on issues of climate change, gender protection and inclusion, Colombia

3. The strengthening of local communities through training on environmental, social and economic topics, reaching nearly 6 800 beneficiaries.

The greenhouse and the community farm are managed by the Association of Veredal Aqueducts of Santa Ana. This community association is responsible for coordinating the actions of the farmers and the community, and they also manage the costs and benefits of production.

Although the scope of the project is limited to implementation of these initial measures, through advocacy actions and the establishment of alliances with strategic stakeholders in the territory, the project is seeking to advance towards the design and implementation of Nature-Based Solutions (NBS).

This process is carried out by the Red Cross and Red Crescent movement funded by the Zurich Foundation and the Spanish Agency for International Cooperation, in order to continue with the implementation of climate resilience and flood resilience actions in rural landscapes.

### 3.5.3 A grassroots response to wildfires in Lebanon

The Mediterranean region is one of the world's most vulnerable climate change hotspots, where temperature is expected to rise 20 percent faster than the global average (MedECC, 2020). With longer heatwaves and extreme drought episodes, the risk, frequency and intensity of wildfires is expected to worsen (Golden, 2023). In the context of warmer and drier summers, Lebanon now faces near-daily wildfires (Mouawad, 2024). Given a shortage of public resources, investments, personnel and funding, grassroots organizations decided to take matters into their own hands (Kayyed, 2023).

The Akkar Trail Association perfectly depicts the people's will to fight for their mountains. The association is an environmental organization, originally established to promote ecotourism and outdoor activities along mountain hiking trails, with a central focus on the Akkar Governorate in North Lebanon (Akkar Trail). However, realizing that between 2019 and 2021 Akkar had lost 14 percent of its forest cover, the team decided to shift its core activities towards firefighting and mountain rescue operations (Casani, 2021).

**Table 3. Summary of Akkar Trail's activity since its inception based on the association's internal data**

| Year | # Rescues | # Fires extinguished | Area burnt (ha) |
|---|---|---|---|
| 2021 | 1 | 35 | 2 503.6 |
| 2022 | 3 | 26 | 143.6 |
| 2023 | 2 | 31 | 266.32 |
| 2024 (as of mid-Augus) | 4 | 17 | 43.8 |

*Source:* Author's own elaboration

After contributing to the establishment and maintenance of more than 30 hiking trails, encompassing a walking distance of 300 km, it was time for Akkar Trail to engage in firefighting and rescue. The operations team was established spontaneously in summer 2020, following the disastrous fires that struck the cedar and pine forests in Akkar (Lazkani, 2020). These forests are invaluable at a national and regional level as they host many endemic plants, animals and emblematic 1 000-year old juniper (*Juniperus excelsa*) and cedar (*Cedrus libani*) trees at an exceptionally high density. These two species are in fact the only trees that grow in Lebanon's highest altitudes, in mountains above 1 500 m a.s.l. (MTV Lebanon, 2020).

***"Many thanks for Akkar Trail for their work, science and love for nature"*** **– Nasser Yassin, Lebanon's Minister of the Environment (Yassin, 2024).**

Today, 15 young volunteers spend sleepless nights safeguarding the forests in their mountains. Through crowdfunding, the team is now equipped with two 4-wheel drive vehicles, considered one of the most successful models in responding to wildfires in rugged areas. They have already succeeded in extinguishing more than 100 fires in different parts of the country and reduced the risk of catastrophic wildfires by over 90 percent (Homsi, 2023).

***"Akkar Trail has reduced wildfires in the area by 96 percent using only two pickup trucks"*** **– Khaled Taleb, Leader of the association (Homsi, 2024).**

On another front, the team tirelessly works on environmental awareness, scientific research, wildlife rescue and seed germination to encourage reforestation. It is documenting biodiversity in Lebanon's northernmost region and currently working on expanding the environmental studies laboratory, which includes a herbarium and an insectarium, to serve as a reference for students and researchers from Lebanon and beyond. Today, the organization also hosts a tree nursery, with 15 000 seedlings of native species to be used in restoration and reforestation (MTV Lebanon, 2024).

Along with its partners, Akkar Trail has been organizing training camps for forest fire response teams across Lebanon for two years. This camp brings together more than 100 volunteers from various regions to exchange experiences and best practices in dealing with forest fires (Akkar Trail, 2024).

*Lazzab* (Arabic for Juniper) and *Shuh* (Arabic for Fir), Akkar Trail's firefighting vehicles in action, Lebanon

Akkar Trail relies primarily on donations and contributions for its funding. As such, the team risks suffering from shortage of equipment and funds to cover the costs of operations, psychological support and maintenance. Given the ongoing economic crisis in Lebanon, the team is in dire need of financial resources to be able to face the rising mental and physical challenges (Kutter, 2023). Moreover, moving forward, investments in firefighting infrastructure are needed, including revamping and installing water networks, hydrants, watchtowers and roads (FundAHope, 2023).

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### 3.5.4 Climate insurance boosts resilience in Kyrgyzstan

The Kyrgyzstan is facing increasingly frequent mudflows, flooding and other climate shocks, causing financial losses. In 2023, the World Food Programme (WFP) launched a Climate Risk Insurance (CRI) project to assist vulnerable households, such as those of Aijan Talasbek Kyzy, impacted by climate change. CRI is a weather index-based insurance policy that covers lack of feedstock due to droughts and harsh winters.

Aijan lives with her husband and four children in the mountainous Naryn province of the Kyrgyzstan. The family lives in a village at 2 600 m a.s.l. – but higher altitudes offer little protection from temperature rises and erratic weather extremes. In particular, droughts interrupt farming and food production and have a particularly serious effect on livestock.

***“There was a lot of rain in spring and no rain during the summer, there was a drought,” says Aijan. “From our fields we usually harvest 800 kg of barley, but this year we harvested only 500 kg. At the end of August, it started raining a lot. By the end of September, it was snowing. We had many losses. Our cattle died.”*** (Aijan Talasbek kyzy, personal interview)

When weather patterns defy expectations, harvests fail. As people struggle to grow crops, there is less hay to stockpile for sustenance during winter, posing a threat to the health of animals. Working with the Government to assist smallholder farmers, in 2023 WFP piloted the country’s first climate-risk insurance scheme, with support from Switzerland.

Disasters caused by climate change – such as droughts, mudflows and floods – are becoming one of the main drivers of food insecurity and malnutrition in the Kyrgyzstan. Indeed, such climate-induced disasters have increased by 150 percent since 2010 (Asian Development Bank and World Bank, 2021).

This project aims to enhance the resilience of rural communities to extreme weather-related risks by providing financial protection against climate-related shocks through insurance.

Aijan lives in the remote and mountainous Naryn province, the Kyrgyzstan

© Giulio Dadamo

***"WFP provided trainings on climate-risk insurance for livestock," says Jipariza Omurkanova, a social affairs specialist at the local government. "And through the insurance, fodder was provided. Fodder is expensive now. As you see, the climate is changing, people can no longer store as much fodder as before."*** (Jipariza Omurkanova, personal interview)

The climate risk insurance pilot is an important step forward in building climate resilience in the Kyrgyz Republic. Its success lies not only in its immediate positive impact on vulnerable families, but also in fostering a more resilient and sustainable future for farmers and food systems in the country.

In 2023, an insurance payout was triggered due to summer drought in the Ak-Talaa district of Naryn province where Aijan lives, benefiting 792 families below the poverty line with 26.3 metric tonnes of barley as feed for their livestock. The barley was chiefly used to help the animals of the most vulnerable groups in the district to stay alive during the long winter period.

WFP, alongside international partners, is committed to further reducing vulnerability to shocks and strengthening the adaptive capacities of rural communities through innovative solutions, such as insurance.

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### 3.5.5 Satellite-based climate risk insurance for farmers in Nepal

Nepal is among the most climate-vulnerable countries, with agriculture – which employs more than two-thirds of the population and contributes significantly to the country's gross domestic product – severely impacted by erratic rainfall, changing pest/disease dynamics and increased droughts (Joshi *et al*., 2021; Garcia, 2018). Despite government subsidies covering 80 percent of insurance premiums, only 1 percent of farmers in Nepal have access to insurance (Perdomo, 2023; Gupta, 2022). PlantSat was established to address such climate and agriculture risks faced by Nepal's smallholder farmers.

PlantSat harnesses satellite, picture and weather data analytics, combined with artificial intelligence and machine learning, to provide precision agriculture intelligence to farmers, insurance companies and extension officers. This digital platform streamlines insurance enrolment by digitizing proposal and technician forms, and enables remote farm monitoring through satellite, weather and geotagged photographs. Insurance companies use this data to assess risks, monitor crop conditions and settle claims promptly, reducing operational costs by 25 percent and making insurance more accessible. By tackling high operational costs and complexities, the service empowers farmers to mitigate agricultural and climate-related risks.

The journey began in 2019 with a vision to empower farmers through satellite-based actionable decisions via the PlantSat Precision Agriculture app. After two years, during which time a network of 2 000 farmers and more than 5 000 ha of digital farms had been created, it became clear that the B2C model required intensive teaching and behavioural change for farmers – a challenge for a startup. In 2022, the company therefore switched to the B2B model by digitizing insurance services, focusing on helping insurance companies to reduce operational costs through picture, weather and satellite-based risk assessments, while protecting smallholder farmers from agricultural and climate risks.

Since then, PlantSat has made significant strides by partnering with international agencies such as the International Maize and Wheat Improvement Center, the United States Agency for International Development-Feed the Future, German development agency GIZ, Winrock International Nepal and the Korea International Cooperation Agency-Global Green Growth Institute. The digital insurance policies now cover more than 6 600 farmers and their crops, such as rice, maize, wheat, oranges, walnuts, legumes and vegetables. Notable outcomes include the first-ever shortfall claim settlements for rice seed producers and the first-ever protection for legume and walnut farmers in Nepal. To date, protection coverage worth USD 1.5 million has been provided.

PlantSat prioritizes the inclusion of vulnerable groups, including women, youth, migrant workers and smallholder farmers in remote areas, who are disproportionately affected by climate change. By reducing the financial impact of crop failures, its services have helped to increase the resilience of such rural mountain communities, enabling them to invest in improved farming techniques, secure income, and adapt to changing climate conditions. The participation of women and youth in these programmes has contributed to building a more digital, inclusive and resilient agricultural system.

To ensure long-term sustainability, PlantSat will expand its services to all non-life insurance companies in Nepal, while refining its business model. Its current revenue strategy includes an NPR 100 000 annual subscription fee for platform maintenance together with an 8 percent charge on the premium from insurance companies per farmer digitally enrolled. There are plans to roll out the model at national level, before scaling out the services to India and Bangladesh and African nations. However, scaling requires addressing key challenges, particularly digital infrastructure. Reliable internet access and mobile phone penetration in rural areas are crucial, alongside initiatives to improve digital literacy and financial awareness for farmers and insurance companies.

A major barrier for scaling is reliance on government-subsidized insurance models. PlantSat believes in gradually transitioning farmers towards paying premiums independently and incentivizing private insurers to expand coverage in underserved areas. Policy reforms, regulatory changes and strong public-private partnerships will be essential to drive innovation and the adoption of climate risk insurance at scale.

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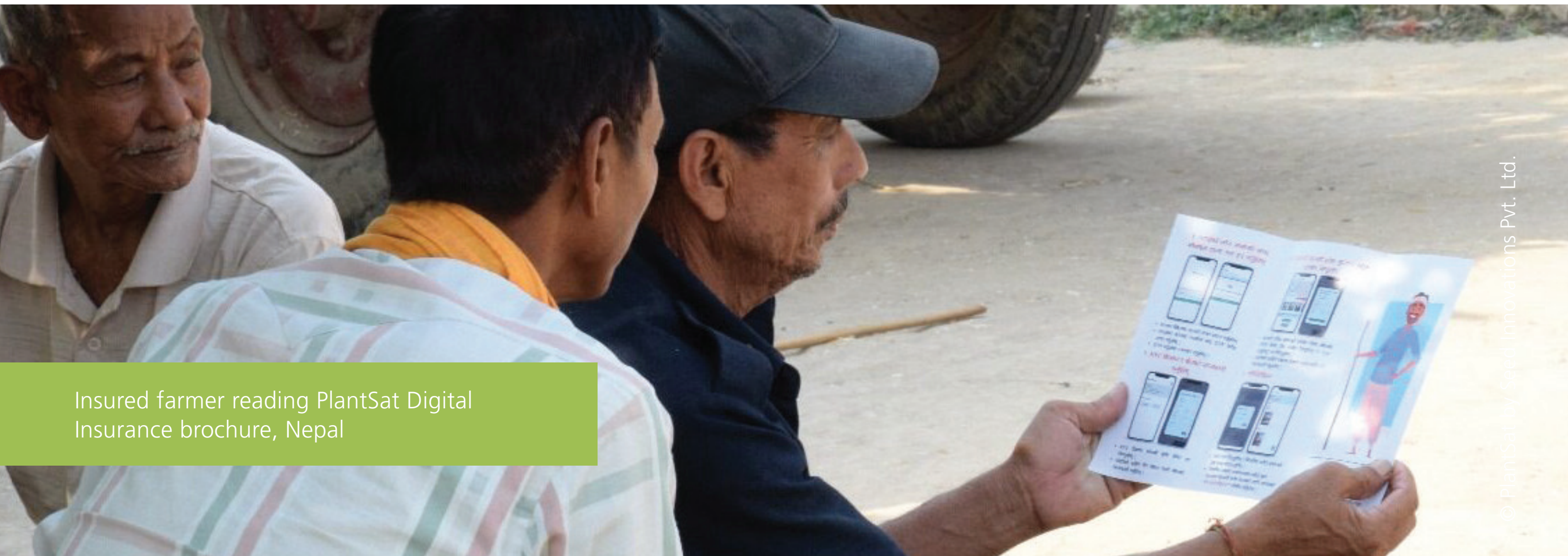

Insured farmer reading PlantSat Digital Insurance brochure, Nepal

© PlantSat by Seed Innovations Pvt. Ltd.

Women farmers discuss results after experimenting with new farming practices Nepal.

© Chris Steele-Perkins/Magnum Photos

# 3.6 Integrating knowledge and education at local level for just adaptation and development

Investing in knowledge and education efforts is an essential foundation for transformational adaptation. In most mountain contexts, increasing people's adaptive capacity and resilience is seriously constrained by remoteness, insufficient access to basic social services, marginalization and exclusion.

At local level, supporting women, youth and other vulnerable members of rural and mountain communities through people-centred learning and empowerment projects is crucial, acknowledging the multiple and intersecting layers of discrimination and mobilizing and building collective local power.

### 3.6.1 Farmer Field Schools

The Farmer Field School (FFS) is one of the most successful examples of FAO's approach to people-centred learning. It has been championed in more than 100 countries by thousands of organizations globally over the past four decades. To date, Farmer Field Schools have empowered more than 20 million farmers to become experts on their land, building their decision-making and innovation capacities and empowering them to drive change collectively.

The FFS approach – characterized by 'grassroots labs' and innovation – can make a major contribution towards building rural communities' adaptive capacity for mitigating risks related to the impacts of climate change and achieving Sustainable Development Goal 13 – Climate action (FAO, 2021).

Farmer Field Schools help communities and farmers to: understand how local farming systems are exposed and sensitive to specific weather threats; identify adaptive solutions, and assess the requirements for using these to strengthen their resilience to climate change stresses; develop context-specific

Women from the Mutambara I Village de la Paix planting cassava under the guidance of technical experts from the Bureau Appui Developpement et Entraide Communautaire (BADEC) and FAO, Burundi

© FAO/Giulio Napolitano

FFS programmes (including field studies and special topics) that respond to the challenges of climate change they have identified; and engage other farmers and the wider community to work in a planned and coordinated effort aimed at addressing climate change risks.

### Box 2. Farmer Field Schools in Burundi

The highlands region of Burundi is affected by environmental degradation that has caused poor crop and livestock productivity, loss of ecosystem services and loss of agrobiodiversity. In addition, the effects of climate hazards and risks cause a significant decline in agricultural production, threaten food security for millions of subsistence farmers and contribute to poverty.

To address these climate-related issues, a project 'Support for Sustainable Food Production and Enhancement of Food Security and Climate Resilience in Burundi's Highlands (RFS)' was established in 2015, implemented by FAO in collaboration with the Burundian Ministry of Water, Environment, Land Management and Urban Planning, and the Ministry of Agriculture and Livestock.

As part of this wide-ranging initiative, Farmer Field Schools were established to provide an opportunity for community members to both learn new skills and techniques and contribute their local knowledge to project interventions. The schools have proved effective in opening up dialogue between the different stakeholders and for putting scientific knowledge into practice. As of 2021, 105 Farmer Field Schools had been established across 58 communes. Based on the success of the approach, the Government of Burundi has institutionalized Farmer Field Schools by using them as part of its toolbox within national extension service plans and strategies for providing technical support to the country's farmers.

The mechanism of Farmer Field Schools has been replicated elsewhere in East Africa, and aligns well with the tendency in the region for farmers to organize themselves into groups.

*Source:* Author's own elaboration

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### 3.6.2 Youth education for local climate change solutions in Kenya

The climate crisis is the defining challenge for today's youth, impacting their environment, physical and mental health, culture and future job prospects. Through its Climate Innovation Challenge (CIC) curriculum, Climate Advocates Voces Unidas (CAVU) engages youth who are most vulnerable to climate change impacts to be part of the solutions, including students from Indigenous communities, communities experiencing acute climate change impacts, and communities burdened by economic disparities.

Just as CAVU challenges students to create locally-led, culturally responsive climate solutions, the organization has adapted its programme to be responsive to the communities it serves. This means incorporating place-based learning that honours students' values and interests.Through this approach, CAVU CIC bridges the gap between traditional textbook learning and career development for positive change, giving meaning and purpose to education and life.

Gully head with a fallen tree, Kenya

© CAVU / Felix Kariuki

CAVU believes that innovative local solutions exist in areas of science, engineering, entrepreneurship and cultural change. When enacted locally, these adaptations make a collective and global difference. The CIC curriculum teaches the science of climate change. It then prompts students to identify climate-related impacts in their communities and design solutions. Students tell the story of those solutions in a short (up to 4 minutes) video that is entered into a contest. CAVU maintains an open library of the winning students' Capstone Projects, which can be accessed online, connecting schools and classes for knowledge and technology exchange.

Mwakingali School, situated at the foot of Mwakingali hills which are part of Kenya's famous Taita hills, has numerous soil erosion gullies next to its classrooms. This is a direct impact of climate change due to increased deforestation, overgrazing and inappropriate farming techniques.

According to research data from the University of Nairobi's Department of Geospatial and Space Technology, annual soil erosion loss in the Taita hills is more than 550 tonnes/ha/year. Analysis of soil sampling from Mwakingali hills indicates significant spatial decrease of soil fertility. Bare exposed sites near the gullies are susceptible to surface crusting, promoting gully head propagation. Rapid expansion of gully systems and significant reduction of soil fertility has serious consequences for future productive use of Mwakingali hills, as well as for the lowlands and foothills.

Through engagement with CAVU, students have been able to research possible solutions, and with the help and understanding of their CAVU CIC-trained teacher, the students identified the building of gabions as the most scalable solution. The strategy was designed to mitigate soil erosion and reclaim soil health and land, thereby restoring the natural habitat and biodiversity and preserving infrastructures in the foothills, including their classrooms. The initial project phases 1 and 2 were implemented by the students themselves in August 2023, with the support of teachers from Mwakingali, neighbouring regions and community members. Gabion mattresses were built in two of the four gullies near Mwakingali Primary School classrooms.

For a scaled impact in the region there is a need for more schools and more students to be engaged in the CIC experiential learning programme. Government, NGOs, community–based organizations, and private organizations need to invest in promoting the growth and development of CIC experiential learning, as well as enabling policies and inclusive green skills-building for women, youth and vulnerable persons, to foster a sustainable economy.

Members showcasing vermiwash solutions to government representatives, Nepal

© ICIMOD/Kailash Bhatta

## 3.6.3 Community Learning Centre for climate-resilient agriculture in Nepal

The Green Resilient Agriculture Productive Ecosystems (GRAPE) project developed the concept of Community Learning Centres (CLCs). These focus on mitigating the effects of climate change on agriculture by showcasing climate-resilient technologies and practices, including context-specific, affordable and nature-based solutions tailored to local agroecological conditions. The CLCs create hands-on learning environments within farming communities, enabling farmers to actively participate in researching, designing and implementing climate-resilient agricultural practices. Based on the principle of 'seeing is believing and learning by doing', 20 CLCs have been established in the Sudurpaschim and Karnali provinces of Nepal.

Situated in one of the most remote parts of the country, the CLC in Dimmerpani, Budhinanda Municipality, Bajura District is run by women farmers who have taken on leadership roles as men migrate for seasonal labour. Central to this initiative is the women-led farmer group *Janabikash Mahila Krishak Samuha*, which comprises 26 members. In 2022, this group began collaborating with the GRAPE project, receiving technical support to improve its agricultural practices. The CLC served as a testing ground for innovative techniques such as vermicomposting, vermiwash,[6] improved composting methods, tricho-compost,[7] plastic houses, drip irrigation, soil cement tanks and biochar. Following the success of these technologies, more than 100 farmers from neighbouring communities adopted the practices, demonstrating the CLC's far-reaching impact.

***"I used to think earthworms were pests and removed them from my fields. After learning about their benefits through vermicomposting training, I built a chamber with two kilograms of worms, which quickly reproduced. With my husband's help, we've sold over 70 kg of earthworms and 200 kg of vermicompost. This has improved crop productivity, and we now supply vegetables to the School Day Meal Program and the Kolti market, Bajura. Inspired by our success, several farmers have started their own vermicomposting chambers."***
Biru Bohara (member of Janabikash women farmers groups)

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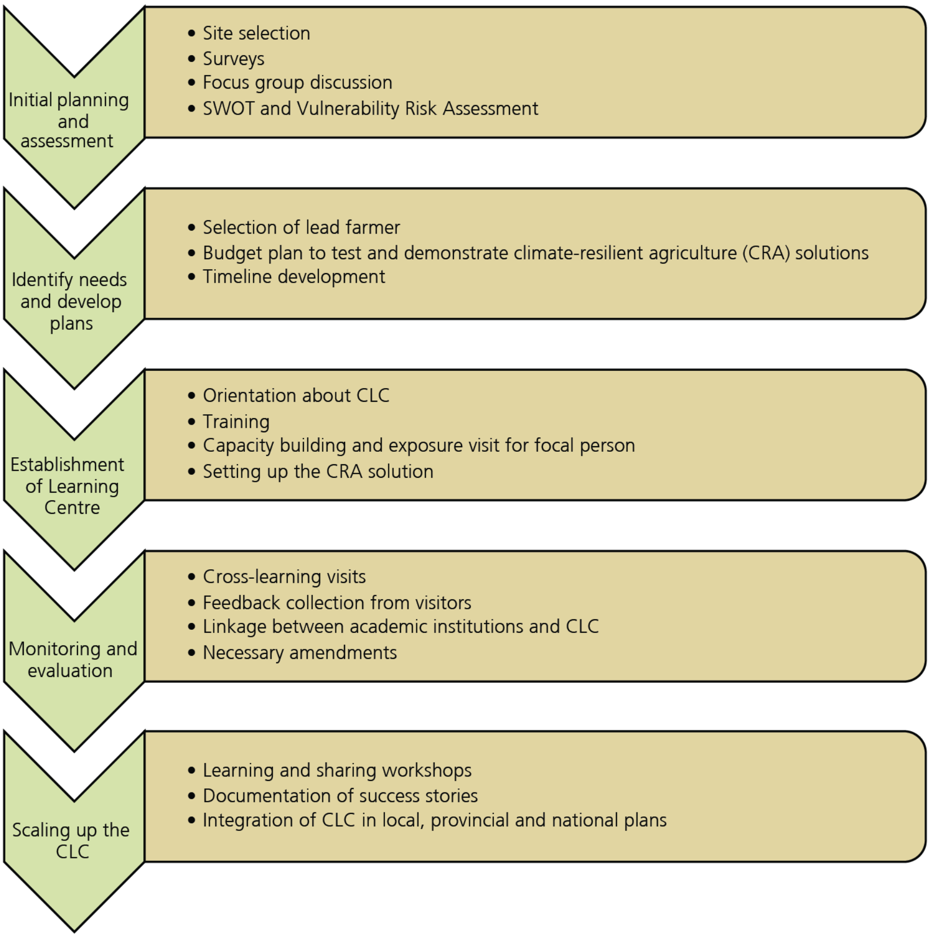
[6] Vermiwash is the liquid that is collected after water passes through compost made by earthworms. It is rich in plant growth hormones, micronutrients, and major nutrients like nitrogen, phosphorous and potassium. https://www.fao.org/family-farming/detail/en/c/1272147/#:~:text=Vermiwash%20is%20the%20liquid%20that,like%20nitrogen%2C%20phosphorous%20and%20potassium.

[7] Tricho-compost is a manure prepared by the composting method using the spores of beneficial fungus known as Trichoderma spp. The fungus acts as an antagonist against the wide range of harmful fungus and nematodes when added to the compost and protects crops against the pathogens. https://www.researchgate.net/publication/337019247_Tricho-Composting_in_Bangladesh

The women of *Janabikash Mahila Krishak Samuha* lead their group meetings, designing and implementing activities. They organize orientation programmes for visiting officials, NGOs, international non-governmental organizations and schools, showcasing their climate-resilient practices. Their knowledge extends beyond their community, with the group offering training to farmers eager to replicate these methods, fostering widespread knowledge transfer throughout Bajura.

To sustain the CLC, the group has introduced an NPR 1 000 interpretation fee for large visiting groups. This revenue is placed in a common fund, supporting further agricultural endeavours and granting the women access to financial resources

**Figure 7. Establishing and scaling Community Learning Centres**


Initial planning and assessment
• Site selection
• Surveys
• Focus group discussion
• SWOT and Vulnerability Risk Assessment
Identify needs and develop plans
• Selection of lead farmer
• Budget plan to test and demonstrate climate-resilient agriculture (CRA) solutions
• Timeline development
Establishment of Learning Centre
• Orientation about CLC
• Training
• Capacity building and exposure visit for focal person
• Setting up the CRA solution
Monitoring and evaluation
• Cross-learning visits
• Feedback collection from visitors
• Linkage between academic institutions and CLC
• Necessary amendments
Scaling up the CLC
• Learning and sharing workshops
• Documentation of success stories
• Integration of CLC in local, provincial and national plans

*Source:* Authors' own elaboration

The CLC model has gained attention from local government officials in Bajura, leading to the adoption of climate-resilient agricultural practices outside the CLC. Himali Rural Municipality has allocated budget and resources to replicate the CLC model, reinforcing the scalability of the initiative.

The success of the Community Learning Centre in Dimmerpani exemplifies how localized solutions can empower communities to build climate resilience. The CLCs serve not only as hubs for learning, but also as platforms for leadership, knowledge exchange and sustainable development. As local governments and neighbouring communities replicate the model, it holds the potential to transform agricultural practices across the region, enabling vulnerable communities in the Hindu Kush Himalaya to adapt to climate change.

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### 3.6.4 Integration of Indigenous Peoples' knowledge for climate adaptation in mountain regions

Indigenous Peoples' knowledge is harnessed for and integrated into various aspects of climate adaptation, helping mountain communities to cope with the adverse effects of climate change. Drawing on 22 examples from the Adaptation at Altitude Solutions Portal, the manner in which Indigenous Peoples' knowledge is used in climate adaptation in mountain regions has been synthesized under five wide-ranging themes: 1) Ecological expertise and biodiversity conservation, 2) Traditional farming techniques, 3) Community cohesion and networks, 4) Cultural and spiritual resilience, 5) Collaboration and knowledge sharing.

Indigenous leader from the Guna People, Púcuro Indigenous Territory, Darien Province, Panama

© FAO/Mauricio Mireles

While numerous success stories are showcased, challenges are also evident, particularly regarding efforts to replicate and upscale locally implemented solutions across other communities and regions, with evidence of mainstreaming of solutions into broader adaptation policies and long-term initiatives seen in only about one-quarter of the solutions. A key prerequisite for mainstreaming and replicating adaptation solutions is ensuring that experience and lessons learned are systematically transferred. In Indigenous communities, where experiences and knowledge are typically exchanged by word of mouth, more institutionalized mechanisms need to be established in order to enhance the distribution of knowledge.

Further analyses across the Adaptation at Altitude Solutions Portal reveal that lack of long-term sustainable financing remains a key barrier to the replication and upscaling of relevant solutions. Most solutions have been implemented under typical 4- to 5-year funding cycles provided by multilateral or bilateral donors, and this short timeframe is insufficient for the ownership and long-term maintenance of projects to be transferred to local stakeholders. One promising avenue for overcoming these limitations is the public-private partnership format, which offers significant potential for the long-term funding of locally-led adaptation solutions. As showcased on the portal, the Fund for the Tungurahua Paramos Management and the Fight Against Poverty was created in 2008 by Indigenous groups and other stakeholders with competencies and interest in guaranteeing the long-term supply of water to rural and urban populations in the Tungurahua province of Ecuador. As well as supporting relevant programmes and projects, annual contributions are used to build the capital of the public-private fund, whose returns can provide longer-term financing. So far, the fund has mobilized nearly USD 5.5 million for ecosystem conservation and the safeguarding of water supplies for the Ambato and Pastaza River basins. The fund has received international recognition, and its experiences have informed the establishment of similar initiatives in Colombia and Peru.

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In the Philippines, a team of experts from the Department of Agriculture is working with officials from FAO to use drones for gathering visual date on damaged rice crops

FAO/Veejay Villafranca

# 3.7 Data and monitoring

Long-term, high-resolution, accurate and accessible data on the multiple interacting components of complex mountain systems around the world can support the design and implementation of strategies to adapt to and mitigate climate change, and to build resilience.

Read more on mountain observations, monitoring, data and information for science policy and society.

Read more on the Systematic Observations Financing Facility (SOFF).[8]

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### 3.7.1 Observations and data for effective adaptation in mountains

*Measuring glacier mass in the Andes*

Since glacier melt in mountain regions plays an important role in providing water to support ecosystems and human livelihoods, monitoring glacier mass balance – the change in ice mass through time – is crucial for designing measures to adapt to the changes.

Developing spatial and temporal consistent mass balance estimates in the Andes is challenging due to the harsh topographical conditions and to budgetary constraints. Monitoring programmes in the region are very scarce; only a few glaciers have long-term and continuous observations dating back to the early 1970s, while *in situ* data collection on most glaciers only started during the 1990s or 2000s. In addition, the methods for calculating glacier-wide mass balance vary from one country to another.

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[8] The Facility, with the Secretariat hosted at the World Meteorological Organization, provides grant funding for the collection of weather and climate data. https://www.un-soff.org/about/

The Revisiting Inter-annual Glacier Mass Balance as a Response to Recent Climate Variability along the Andes project brought together ten Andean research institutes to homogenize the raw glaciological mass balance datasets of ten Andean glaciers located from 15°N to 54°S. Using statistical and geostatistical approaches, an accurate and spatiotemporally consistent and comparable dataset was produced. The dataset has been released via a public-facing website, and has the potential to support informed decision-making for water management and climate change adaptation.

*An online platform to monitor mountains in Central Asia*

Environmental monitoring has been conducted at specific sites across the mountains of Central Asia for many years. However, until the recent formation of the Central Asia Mountain Observatory Network (CAMON), opportunities for sharing data and capacities between these sites and beyond were limited. In the project CAMON Open Science, CAMON was supported in developing an online platform to provide information on the monitoring activities, as well as in compiling and publishing novel regional datasets related to climate, mountain cryosphere, hydrology, hydrochemistry and water stable isotopes. Data on glacial lake outburst flood and non-outburst debris flows have also been shared with stakeholders to enable risk evaluation. Currently, only data for Kazakhstan are shared, but expansion to other countries is planned.

*Meteorological data rescue and digitization in Kenya's mountains*

Through a collaboration between the Kenya Meteorological Department (KMD) and MeteoSwiss, invaluable records from numerous stations were rescued, digitized and made available, complementing other long-term climate records. The data were also integrated into KMD's database.

The Supporting Ecosystem Conservation in Kenya's Mountain Regions through Meteorological Data Rescue and Digitisation project engaged governmental and non-governmental entities, research institutions, nature conservancies and community-based organizations that manage observation stations. Local community members were encouraged to share any available historical weather records and were actively involved in the data rescue process.

Ongoing technical support, including regular equipment checks and maintenance, will be provided to enhance the quality of observations. Community engagement will also continue beyond the project, including through the provision of digital archiving solutions to efficiently store data and minimize losses. The co-development of climate information services with communities will support decision-making in ecosystem conservation.

*Management of risk data in the Hindu Kush Himalayas*

Data to support extreme event hazard and risk assessments in the high mountains of Asia are often lacking – either non-existent or unavailable. In response, the Curation of Risk Data for High Mountain Asia project brought together several early-career scientists and practitioners from across the region to compile and make available relevant existing datasets via an open portal. The initiative also provided the opportunity for an exchange of experiences and capacities. In time, additional datasets will be shared in the same fashion.

Knowledge and increased trust between regional stakeholders regarding data access and exchange have arisen from the project. This has enabled, for example, the production of rapid post-event response reports on disasters that are accessible to local communities in their language and which, using past data, provide context.

The data and insights yielded by these projects have the potential to help scientists and local communities detect and understand ongoing processes of change in mountain environments, and to support the development of more reliable predictive models – which can in turn be used to support decisions. These projects also demonstrate the contribution of collaborative and community-led efforts to addressing systematic observation gaps, as called for by Decision 22/CP.27 of the UNFCCC.

The projects were part of the GEO Mountains Small Grants Scheme 2023.

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Participants in the Assisted Natural Reforestation (ANR) project clearing brush and defining a fire line to protect an area from forest fires, Philippines

# 4

# The way ahead for climate action in mountains

© Noel Celis

Smallholder farmer working in the fields, Nepal

© Chris Steele-Perkins/Magnum

Future risks in mountain regions, particularly at higher warming levels, require a systemic transition towards transformative adaptation. Resilience and adaptation of mountain ecosystems and people depend on ambitious mitigation to reduce greenhouse gas (GHG) emissions, addressing drivers of vulnerability such as poverty, isolation and gender inequalities, and mobilizing financial resources that are adequate to the scale of the actions required (UNEP, 2023).[9]

Policies should facilitate equal access to climate-smart technologies and offer financial and technical support to help farmers adopt sustainable and resilient practices. Innovation is indispensable for addressing complex mountain-related issues. It encompasses technological advances, such as digital solutions for monitoring and conservation, as well as creative problem-solving, such as novel approaches to resource management and financing, and to integrating upland-lowland and rural-urban interactions for disaster risk reduction and urban planning and development. These technologies must be accessible to those with limited resources.

Including small-scale producers, women and youth in the development and implementation of these solutions – for example by integrating them within social protection systems designed to reach the rural poor – is crucial to ensure equitable participation, enabling all farmers and small-scale actors to contribute to and benefit from climate action efforts.

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[9] The New Collective Quantified Goal on Climate Finance (NCQG) is the new global climate finance goal that was set by UNFCCC parties at COP 29 in November 2024. https://unfccc.int/sites/default/files/resource/cma2024_L22_adv.pdf.

The active, meaningful and inclusive participation of youth in decision-making is essential for ensuring the long-term sustainability of mountain solutions, supported by climate education to change behaviours at all levels, including in urban and downstream areas. The international policy landscape is currently looking promising for mountain issues. Under the UNFCCC, mountains are a priority theme for the Nairobi Work Programme and are included in the global stocktake text that parties agreed to undertake at UNFCCC COP 28. In addition, the first Expert Dialogue was held at the Bonn climate Conference Change in June 2024 under SBSTA. Several UNFCCC mountainous country parties are requesting the dialogue to become a recurring event, highlighting the importance of this ecosystem in the climate change agenda. Also, the negotiating Group of Mountain Partnership was officially formed ahead of COP 28 and is entirely dedicated to supporting the mountain agenda within UNFCCC COPs.

The UN General Assembly proclaimed the 5 Years of Action for mountains 2023-2027. A taskforce composed of 26 intergovernmental organizations, including 12 different UN agencies, was created to support its implementation. At the request of the FAO Council, which in December 2023 recognized and reaffirmed FAO's leading role as the main agency for sustainable mountain development within the United Nations system, a Global Action Plan on Mountain Regions Development 2023–2027 was developed and endorsed by FAO's governing bodies.

The UN Decade on Ecosystem Restoration (with its Mountain Flagship programmes), the International Year of Glacier Preservation 2025, and the International Year of Rangelands 2026 are also opportunities for global advocacy and transboundary cooperation on mountain- and climate-related issues.

Parties to the UNFCCC should use formal national climate change communication and planning spaces to strengthen the integration of mountains and mountain food systems into the new cycle of nationally determined contributions (NDC 3.0) starting in 2025, and into national adaptation plan development and update processes. These commitments, and their implementation and reporting, will be most efficient if mountain stakeholders are engaged, and empowered to contribute.

National adaptation plans (NAPs) are voluntary instruments established under the UNFCCC – through the Cancun Adaptation Framework in 2010 – that guide countries' efforts to reduce vulnerability and build adaptive capacity and resilience to climate change impacts.

As of October 2024, 58 countries had submitted NAPs, and several of those countries make specific reference to the importance of protecting and building resilience in mountain areas. For instance, Morocco provides a good example of how countries can use NAPs to drive sustainable development in mountain areas. The NAP provides a comprehensive list of adaptation and resilience objectives for mountain areas, covering everything from food security, livelihoods, ecosystem restoration and biodiversity conservation to water and energy provision, data and innovation, and increased climate investment (FAO, forthcoming).

Priorities for mountain food systems in NDCs and NAPs include encouraging a more holistic understanding of agriculture – one that is not only a system for producing healthy food, but also for ensuring healthy soil, biodiversity conservation, clean water, sustainable landscape management and resilient livelihoods for communities; scaling up sustainable and agroecological practices that enhance biodiversity in agriculture, pasture and forestry and rehabilitate the functions of degraded natural systems; decoupling food production from fossil fuels; shifting to renewable energy for food processing and transport; and evaluating water trade-offs (FAO, 2023).

Loss and damage has emerged as a third key pillar of climate policy, alongside mitigation and adaptation, to address ever-increasing climate impacts in developing countries that are particularly vulnerable to the adverse effect of climate change. Given the slow progress in mitigating GHG emissions and in adapting to climate risks, further loss and damage is unavoidable (UNEP, 2023). The UNFCCC Loss and Damage Fund could enhance climate funding in many mountain countries.

Additional investment in prevention, anticipation and emergency preparedness is also required.

Scaling up climate finance for social protection can play a key role in advancing inclusive and resilient climate adaptation, mitigation and loss and damage in rural settings through its focus on poorer, vulnerable and at-risk populations.

The Harmoniya4Resilience initiative, a joint project of the COP 29 Presidency and the FAO aims to strengthen the role of local actors (small-scale producers, women, youth and Indigenous Peoples) as essential agents of change.[10] It will also aim to mobilize finance for climate actions – low carbon, resilience-building – that reach local level, in particular the most vulnerable populations in mountain regions.

### Initiatives for accelerating climate action in mountains in the short term include:

- ensuring integration of mountain stakeholders in climate planning, implementation, monitoring and reporting efforts;
- a work programme on mountains under the UNFCCC;
- high-level dialogues at COP 29 in Baku, Azerbaijan and at COP 30 in Belém, Brazil;
- promoting recurrent mountain dialogues, and promoting interregional exchange;
- integrating mountains across thematic discussions in negotiations;
- Improving means of implementation, with simplified access, recognizing constraints in mountainous countries, including funds for loss and damage;

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[10] An initiative by the COP 29 Presidency and FAO that was launched at COP 29

- mainstreaming mountain adaptation into other conventions and negotiation spaces (such as the CBD, the UNCCD, the Ramsar Convention on Wetlands and other multilateral environmental agreements) and in relevant financial mechanisms;

- supporting through training programmes negotiators in the UNFCCC and other multilateral environmental agreements to enhance the integration of mountain aspects in these important processes; and

- establishing a stronger connection between actions, including the monitoring frameworks in design undertaken under the CBD and UNFCCC, as relevant to climate change adaptation.

In the context of the negotiations under the UNFCCC on issues related to the Global Goal on Adaptation (GGA), the Conference of the Parties serving as the Meeting of the Parties to the Paris Agreement (CMA) reached a new milestone in 2023 with the adoption of the UAE Framework for Global Climate Resilience under Decision 2/CMA.5. The UAE Framework has the objective to provide guidance for the achievement of the Global Goal on Adaptation and the review of overall progress towards this goal, with a view to reducing the adverse impacts, risks and vulnerabilities associated with climate change and enhancing adaptation action and support. This included the definition of seven adaptation targets (paragraph 9) by 2030 related to water (9a), food and agriculture (9b), health (9c), ecosystem and biodiversity (9d), infrastructure and human settlements (9e), poverty (9f), and cultural heritage (9g), as well as four targets in relation to the dimensions of the iterative adaptation cycle (paragraph 10) on impact, vulnerability and risk assessment (10a), planning (10b), implementation (10c), and monitoring, evaluation and learning (10d). The decision also launched the biennial UAE-Belém work programme on indicators for measuring progress achieved towards these eleven targets, including the identification, and as needed, development of indicators and potential quantified elements.

Eventually, the work programme is expected to identify indicators by the 30th session of the Conference of the Parties (COP 30) in 2025 that will help to monitor progress at the global and national levels. Countries are thus invited to voluntarily include quantitative and/or qualitative information related to these targets in their adaptation communications, biennial transparency reports (BTRs), national adaptation plans (NAPs), national communications and nationally determined contributions (NDCs).

In 2024, Parties and observers to the UNFCCC submitted suggestions and examples of indicators. Among the 5 339 resilience, adaptation and climate impact indicators received by the UNFCCC Secretariat, more than 80 were linked to mountains, altitude or glaciers. Mountain-related indicators have been tagged and identified as relevant for different targets, including ecosystems, food and agriculture, health and disaster risk reduction. For example, for target 9b on food and agriculture, 16 mountain-related indicators were directly mentioned. Similarly, mountain-specific indicators were proposed by Bhutan and ICIMOD in their submissions, and SDG indicator 15.4.2, related to monitoring land cover and land use in mountain areas and under FAO custodianship, was one of the most frequently proposed indicators.

As an observer and under its mandate on agrifood systems, FAO submitted its views to the UNFCCC, in particular under target 9b, on "attaining climate-resilient food and agricultural production and supply and distribution of food, as well as increasing sustainable and regenerative production and equitable access to adequate food and nutrition for all". It proposed the development of indicators linked to other international agreements, in particular the Sustainable Development Goals and the Sendai Framework for Disaster Risk Reduction, including indicators related to mountains and their adaptation. FAO also suggests that the set of indicators for measuring progress should cover the four areas corresponding to the global goal on adaptation, that is: 1) vulnerability reduction; 2) adaptive capacity/adaptive action; 3) resilience and sustainable development; and 4) climate risks and hazards. This will ensure that existing indicators are climate-relevant and appropriate for measuring progress on the GGA.

Sharing best practice in the year 2024 to 2025 will be essential to identify the most effective indicators for monitoring and reporting on progress made in the adaptation of mountain areas. Similarly, further capacity and support will be required at all levels to strengthen understanding, monitoring and implementation of adaptation measures, in line with the targets set in relation to the dimensions of the iterative adaptation cycle under the UAE framework. This will be key to achieving the global goals on adaptation and improving preparedness for the changes we face now and in the future.

See FAO's publication: Using metrics to assess progress towards the Paris Agreement's Global Goal on Adaptation.

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### Further reading

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# Annex 1. Overview of the adaptation practices from the case studies

### Table A1. Sustainable crop and livestock practices

| Case study | Region/Country | Climate-related risks and impacts | Adaptation technology/practice implemented |
|---|---|---|---|
| Building local capacity and leadership in high mountain communities in Colombia | Colombia | Land degradation and biodiversity loss | Participatory collection, analysis and dissemination of key agrifood systems information and impacts of climate change;<br>community climate action laboratories;<br>agroecological practices: community nurseries, rescue and utilization of native tubers, beehives and the optimization of irrigation systems;<br>certification of agriculture adapted to climate change. |
| Alpine farmers face up to climate change | Europe (France and Italy) | Changes in mountain grasslands and management | Development of an integrated method to assess and test effective adaptation measures, combining policy analysis, modelling based on remotely sensed imagery, and participatory processes with farmers, technicians, shepherds, researchers and officials of local institutions. |
| Valuing camelids in the Andes | South America | Droughts and increased temperatures | Reviving of traditional capture, shearing and release back to nature of wild *vicuñas*; educational programmes; increasing livelihood resilience through local value addition for high-quality fibre products from camelids. |
| Stingless beekeeping and conservation in Lambayeque, Peru | Peru | Degradation of natural habitats and a decline in biodiversity linked to unpredictable rainfall and rising temperatures | Restoration of native forests and establishing stingless bee colonies; increasing livelihood resilience through honey production and sale; community involvement and women's empowerment. |

*Source:* Authors' own elaboration

### Table A2. Water management for adaptation

| Case study | Region/Country | Climate-related risks and impacts | Adaptation technology/practice implemented |
|---|---|---|---|
| Rewetting Andean wetlands to enhance water availability | South America | Degradation of Andean high mountain *pàramo* ecosystem (predominantly grasslands on soils with high organic carbon content) linked to increased warming | Improving water regulation and yield through restoration of previously drained wetlands: reduce water energy during high-flow events, create small dams, and generate favourable peat accumulation conditions. Mitigation co-benefits. |
| Reviving traditional water management systems in the Himalayas: the Zing and Kul systems | India | Drought, variability in rainfall | Traditional technologies to store water from snow melt and glacial streams in ponds (Zing) and from mountain springs and streams in channels (Kul) to support irrigation.<br>Contribution to food security and livelihood resilience. |

| Case study | Region/Country | Climate-related risks and impacts | Adaptation technology/practice implemented |
|---|---|---|---|
| Local solutions for a greener, more resilient Anti-Atlas, Morocco | Morocco | Declining precipitation and groundwater levels, and excessive heat | Construction of a small dam and of thresholds for water capture upstream; planting of fruit trees; designation of the area as a protected zone. |
| Artificial glaciers in Kyrgyzstan | Kyrgyzstan | Increased aridity linked to unreliable precipitation patterns and more frequent peaks especially in mountain pastures | Construction of underground pipeline to bring water from upstream to pasture. In the cold season the water freezes and stores water that will be used when it melts. |

*Source:* Authors' own elaboration

### Table A3. Protected areas, forests, green cities

| Case study | Region/Country | Climate-related risks and impacts | Adaptation technology/practice implemented |
|---|---|---|---|
| Safeguarding the future of Alpine Ash forests in southern New South Wales, Australia | Australia | Biodiversity loss and risk of extinction of iconic forests due to increased frequency of wildfires | Establishment of seed banks for two Eucalyptus species. Seedbanks act as insurance against the increased frequency of fires in the landscape and to mitigate against other climate risk factors including pest and disease. |
| Sustainable management of Togo-Ghana Highlands | Togo | Extreme weather events causing erosion, land degradation and biodiversity loss | Establishment of protected areas; participatory ecosystem restoration activities (tree planting, vegetation recovery, butterfly farming; combination of scientific and traditional knowledge to restore natural capital). |
| Setting the adaptation agenda for Patagonia's World Heritage | Argentina | Glacier melting and glacial lake outburst floods linked to increased temperatures | Participatory adaptation planning with local women and women-led advocacy. |
| Medellin miracle city | Colombia | Increased risk of landslides and floods, increased heat island effect | Urban park management, urban tree planting, green roof gardens, food production. Interventions have improved living conditions, focusing on the most disadvantaged communities. |

*Source:* Authors' own elaboration

### Table A4. Social business entrepreneurship and sustainable investments in mountain value chains

| Case study | Region/Country | Climate-related risks and impacts | Adaptation technology/practice implemented |
|---|---|---|---|
| Co-creating a sustainable future in the mountain destination of St. Corona am Wechsel, Austria | Austria | Reduction in snow cover due to warmer temperatures | Innovative uses of existing infrastructure to allow year-round tourist activities. |

| Case study | Region/Country | Climate-related risks and impacts | Adaptation technology/practice implemented |
|---|---|---|---|
| Emerging risks; mountain guides adapting | Global | Loss of historical climbing routes and iconic landscapes due to warming | Educational activities for mountain instructors and guides on climate-related mountain hazards with skill sets based on science, local knowledge and best practices. Improved mountain guiding also contributes to mitigation. |
| Business Incubator and Accelerator programme in Mongolia | Mongolia | Increased the frequency and intensity of extreme weather events like storms, floods and droughts, with negative impact on biodiversity, and on livelihoods and agricultural productivity | Reduction of textile industry environmental footprint, including excessive raw material extraction; promotion of sustainable grazing techniques by local herders; improved animal care practices. |
| New business for forestry workers in China | China | Changes in biodiversity linked to climate change have added to the historical losses of species and ecosystems due to unsustainable use of natural resources | Support to sustainable ecotourism as alternative income generation for local people in response to the commercial logging ban in this flagship protected area in northeast China. |

*Source:* Authors' own elaboration

### Table A5. Building resilience to manage disaster and climate risk for mountain people

| Case study | Region/Country | Climate-related risks and impacts | Adaptation technology/practice implemented |
|---|---|---|---|
| Disaster risk reduction and green development in mountain areas of China | China | Increased occurrence of climate-induced disasters | Development and implementation of green disaster reduction, green industry development, community risk management, and related policy mechanisms for promoting disaster mitigation and green development synergies. Education programmes for disaster awareness and disaster prevention capacity. |
| Climate resilience in rural landscapes of Colombia | Colombia | Floods, droughts and high temperatures | Planting of high density species for soil retention and stabilization, rain interception, for reducing erosion and improving flood buffering capacity. Growing of food species to improve food security for vulnerable local population. Educational programmes for local people. |
| Grassroots fire management | Lebanon | Risk, frequency and intensity of wildfires is expected to worsen, linked to longer heatwaves and extreme drought episodes | Establishment and maintenance of hiking trails; firefighting and rescue interventions; environmental awareness, scientific research, wildlife rescue and seed germination to encourage reforestation. |
| Climate insurance in Kyrgyzstan | Kyrgyzstan | Increasingly frequent mudflows, flooding and other climate shocks, causing financial losses | Development of climate risk insurance, a weather index-based insurance policy that covers lack of feedstock due to droughts and harsh winters. |

| Case study | Region/Country | Climate-related risks and impacts | Adaptation technology/practice implemented |
|---|---|---|---|
| Farmer insurance in Nepal | Nepal | Erratic rainfall, changing pest/disease dynamics and increased droughts that severely impact the agriculture sector | Satellite and weather data analytics, combined with AI and machine learning, to provide precision agriculture intelligence to farmers, insurance companies and extension officers. |

*Source:* Authors' own elaboration

## Table A6. Integrating knowledge and education at local level for just adaptation and development

| Case study | Region/Country | Climate-related risks and impacts | Adaptation technology/practice implemented |
|---|---|---|---|
| Farmer Field Schools in Burundi | Global and Burundi | Climate hazards and risks that cause significant decline in agricultural production and threaten food security for farmers | Establishment of Farmer Field Schools to provide an opportunity for community members to learn new skills and techniques and to contribute their local knowledge. |
| Youth education for local, culturally fit climate-change solutions in Kenya | Kenya | Increased extreme events, adding to deforestation, overgrazing and inappropriate farming practices causing soil erosion and increased risk of landslides | Together with students, identification and construction of gabions as the most impactful solution for reducing soil erosion and help in restoring the natural habitat and biodiversity and the preservation of infrastructure. |
| Community Learning Centre for climate resilient agriculture in Nepal | Nepal |  | Create hands-on learning environments within farming communities, enabling farmers to actively participate in researching, designing and implementing climate-resilient agricultural practices testing ground for innovative techniques such as vermicomposting, vermiwash, improved composting methods, tricho-compost, plastic houses, drip irrigation, soil cement tanks and biochar. |
| Integration of Indigenous knowledge for climate adaptation in mountain regions | Global and Ecuador | Loss of cultural identity, biodiversity loss | Public-private partnerships for the long-term funding of locally-led adaptation solutions. Creation of a public-private fund by Indigenous groups and other stakeholders for guaranteeing the long-term supply of water to populations and ecosystem conservation. |

*Source:* Authors' own elaboration

## Table A7. Data and monitoring

| Case study | Region/Country | Climate-related risks and impacts | Adaptation technology/practice implemented |
|---|---|---|---|
| Observations and data for effective adaptation in mountains | Global and Himalaya, Central Asia, Andes, Kenya | Glacier melting, GLOF, extreme weather events | Production, harmonization and release of dataset for risk evaluation; involvement of local community members in data rescue and sharing of available historical weather records. |

*Source:* Authors' own elaboration

Mountains are the lifelines of our planet, serving as vital reservoirs of biodiversity, water and culture. Mountain communities, long recognized for their ingenuity in adapting to harsh conditions, continue to demonstrate remarkable resourcefulness in addressing the unprecedented challenges of a changing climate. However, their resilience is being severely tested by accelerating global warming and the cascading effects of glacier melting, declines in water availability and increasingly frequent extreme hazards, such as floods and landslides.

Around the world, efforts are being made to ensure a sustainable future for mountain regions. This publication showcases mountain adaptation solutions being adopted globally, including sustainable crop, livestock and water management practices, use of protected areas, data and monitoring, and the promotion of social business enterprises. These communities are not just surviving – they are thriving through innovation and adaptation, finding solutions that will impact their lives.

Central to such efforts are local actors – particularly women, Indigenous Peoples and youth – as key agents of change. This publication highlights the importance of their active and meaningful participation in decision-making to ensure the long-term sustainability of mountain solutions. The Five Years of Action for the Development of Mountain Regions 2023-2027 provides the critical framework needed to place mountain areas at the forefront of global sustainable development and climate action.

Based on 26 case studies from around the world, this publication recognizes the importance of blending innovation and tradition when designing adaptation strategies for mountain regions. However, it also acknowledges the scale of the challenge ahead. It should be considered as a global call to action to safeguard the giants of the planet.

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